ПСИХОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ В ОБРАЗОВАНИИ

УДК 37.03 DOI: 10.17853/1994-5639-2023-5-135-154

METACOGNITION & LEARNING PROCESS: USING THINK-ALOUD PROTOCOL (TAP) TO UNDERSTAND STUDENTS AND THEIR TEACHER'S REFLECTION PROCESSES DURING A PROBLEM-SOLVING SITUATION

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Abstract. *Introduction.* Today, the act of teaching has become increasingly intricate. Multiple fields of science now aid in comprehending this complexity, enabling instructors to support learners throughout their educational journey.

Aim. The main *aim* of this study is to determine cognitive and metacognitive thinking process of students and their teachers during a problem-solving situation.

Research methodology and methods. The authors used think-aloud protocol (TAP) in which students (12 participants at the same level) were asked to verbalise their thoughts during a learning activity (math exercise and written production). Similarly, during a pedagogical intervention, nine participants with varying levels of professional experience were required to articulate their professional practices as educators. It should be noted that our approach is purely qualitative following Ericsson and Simon's approach, from data collection step to coding system and processing of these data.

Results and scientific novelty. The results showed that half of the students solved well what was asked in the problem-solving situation, contrary to the other participants who found particular difficulties in each type of situation proposed (in math and in written production). For the teachers, their verbalisations tend towards three aspects with a degree of dominance for each teacher. The authors consider

that their research is a first step towards a new approach of evaluation of the teaching-learning act that includes both the teacher and the learners simultaneously.

Practical significance. The results obtained can be used by pedagogical practitioners to better understand how their learners think on the one hand and develop their professional practices on the other.

Keywords: learning process, think-aloud protocol (TAP), problem-solving situation, student, teacher.

For citation: Bouiri O., Lotfi S., Talbi M. Metacognition & learning process: Using think-aloud protocol (TAP) to understand students and their teacher's reflection processes during a problem-solving situation. *Obrazovanie i nauka = The Education and Science Journal*. 2023; 25 (5): 135–154. DOI: 10.17853/1994-5639-2023-5-135-154

МЕТАКОГНИЦИЯ И ПРОЦЕСС ОБУЧЕНИЯ: ИСПОЛЬЗОВАНИЕ ПРОТОКОЛА «ДУМАЙ ВСЛУХ» ДЛЯ ПОНИМАНИЯ ПРОЦЕССОВ РЕФЛЕКСИИ УЧЕНИКОВ И ИХ УЧИТЕЛЯ В СИТУАЦИИ РЕШЕНИЯ ПРОБЛЕМЫ

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Аннотация. *Введение.* В настоящее время процесс преподавания становится все более сложным. Многочисленные области науки в настоящее время помогают понять эту сложность, позволяя преподавателям поддерживать учащихся на протяжении всего их учебного пути.

Цель. Основной целью данного исследования является определение когнитивного и метакогнитивного процессов мышления студентов и их преподавателей во время решения проблем.

Методология, методы и методики. Авторы использовали протокол «думай вслух», в котором студентов (12 участников одного уровня) просили вербализовать свои мысли во время учебной деятельности (математическое упражнение и письменная работа). То же самое касается и их учителей (9 участников с разным стажем работы), которые должны были выразить словами свою профессиональную практику во время педагогического вмешательства. Следует отметить, что данный подход является исключительно качественным, следуя подходу Эриксона и Саймона – от этапа сбора данных до системы кодирования и обработки этих данных.

Результаты и научная новизна. Результаты показали, что половина студентов хорошо решила то, что было задано в ситуации решения проблемы, в отличие от других участников, которые обнаружили особые трудности в каждом типе предложенной ситуации (в математике и в письменной работе). Что касается учителей, то их вербализация направлена на три аспекта с определенной степенью доминирования для каждого учителя. Авторы считают, что их исследование является первым шагом к новому подходу к оценке акта обучения, который включает как учителя, так и учащихся одновременно.

Практическая значимость. Полученные результаты могут быть использованы педагогами для лучшего понимания того, как их ученики думают, с одной стороны, и развития их профессиональной практики, с другой.

Ключевые слова: учебный процесс, протокол «думай вслух», ситуация решения проблем, студент, преподаватель.

Для цитирования: Буири У., Лотфи С., Талби М. Метакогниция и процесс обучения: использование протокола «думай вслух» для понимания процессов рефлексии учеников и их учителя в ситуации решения проблемы // Образование и наука. 2023. Т. 25, № 5. С. 135-154 DOI: 10.17853/1994-5639-2023-5-135-154

PROCESO DE METACOGNICIÓN Y APRENDIZAJE: USO DEL PROTOCOLO DE "PENSAR EN VOZ ALTA" (TAP) PARA COMPRENDER LOS PROCESOS DE REFLEXIÓN DE LOS ESTUDIANTES Y SUS PROFESORES DURANTE UNA SITUACIÓN DE RESOLUCIÓN DE PROBLEMAS

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Abastracto. *Introducción.* En la actualidad, el proceso de enseñanza se torna cada vez más complejo. Numerosos campos de la ciencia ahora centran todos sus esfuerzos para comprender esta complejidad, lo que ha permitido a los educadores apoyar a los estudiantes a lo largo de su viaje de aprendizaje.

Objetivo. El objetivo principal de este estudio es determinar los procesos cognitivos y metacognitivos del pensamiento de los estudiantes y sus profesores durante la resolución de problemas.

Metodología, métodos y procesos de investigación. Los autores utilizaron el protocolo de "pensar en voz alta" en el que se pedía a los estudiantes (12 participantes del mismo nivel) que verbalizaran sus pensamientos durante una actividad de aprendizaje (ejercicio de matemáticas y escritura). Lo misma operación concernía a sus docentes (9 participantes con diferente antigüedad), quienes debían verbalizar su práctica profesional durante la intervención pedagógica. Cabe señalar que este enfoque es extremadamente cualitativo, siguiendo el enfoque de Erickson y Simon, desde la etapa de recopilación de datos hasta el sistema de codificación y procesamiento de datos.

Resultados y novedad científica. Los resultados mostraron que la mitad de los estudiantes pudo resolver adecuadamente lo propuesto en la situación de resolución de problemas, en contraste con el resto de los participantes, quienes encontraron dificultades particulares en cada tipo de situación propuesta (en matemáticas y en el trabajo escrito). En cuanto a los docentes, su verbalización se dirige a tres aspectos con cierto grado de dominancia para cada docente. Los autores creen que su estudio es el primer paso hacia un nuevo enfoque de la evaluación del acto de aprender, que incluye tanto a profesores como a alumnos al mismo tiempo.

Significado práctico. Los resultados obtenidos pueden ser utilizados por los educadores para comprender mejor por un lado, cómo piensan sus alumnos, y por otro lado, para desarrollar su práctica profesional en lo que concierne a su actividad como pedagogos.

Palabras claves: proceso educativo, protocolo "pensar en voz alta", situación de resolución de problemas, alumno, profesor.

Para citas: Bouri O., Lotfi S., Talbi M. Proceso de metacognición y aprendizaje: Uso del protrocolo de "pensar en voz alta" para comprender los procesos de reflexión de los estudiantes y de sus profesores en situaciones de resolución de problemas. *Obrazovanie i nauka = Educación y Ciencia.* 2023; 25 (5): 135–154. DOI: 10.17853/1994-5639-2023-5-135-154

Introduction

To verbalise is to put words on your practice experience in order to make them knowledge, "to teach students to go beyond intuitions to give themselves the means to have intentions, therefore to express themselves and take a position, to think and communicate with plastic languages". In teacher training, reflection is essential to learning and developing a professional profile. According to E. G. Bugg and J. Dewey [1], reflection makes teaching more knowledgeable and reflective. Reflections can be different in many ways and superficial in content, such as topics, performance, or ethics. J. Luttenberg and T. Berger [2] noted that different reflection levels, for example when reflections move from subjectivity to abstraction and subsequently to theory, are related to changes in consent. They are sometimes described as critical and should then include questions such as "what?" and "why?" in order to gain a deeper understanding of teaching process [3].

Teacher dialogue refers to the nature and frequency of teacher's verbal interactions with student. Interestingly, teachers spend a great time deal talking to learners, but this interaction is often with whole classes rather than individuals [4]. In a teacher's study, S. Kontos [5] found that nearly 75% of verbalisations fell into one of four categories: play support with statements, play support with questions, and play support with questions of practical/personal support, and positive social contact.

Relating to student, thinking aloud is when he/she can verbalise their actual thoughts while reading a book for example [6]. Language teachers create reading assignments by understanding extremely diverse strategic processes. They may also be interested in conducting behavioural research that explores realistic reading tasks and problem-solving approaches for learners using collaborative thinking and speaking exercises in the classroom [7] after group training.

Students, who are able to master their internal discourse, which is a kind of thinking aloud or interacting effectively with their partners while executing the steps of the strategy demonstrate a superior ability to accomplish pedagogical tasks [8, 9]. Mindful questioning can have a significant effect on students' metacognitive strategies [9]. By asking thoughtful questions, students can select and apply strategies while increasing their awareness of how and why they use them.

Think-aloud protocol (TAP) collects data by verbalising thoughts in real time or after while a person is solving a problem or engaging in other cognitive activities.

It aims to uncover key elements of specific reflective processes; essentially asking participants to say aloud "what's going on in their head" while performing a task and enhances the mental activity to put words into words [10, 11, 12]. The extracted verbalisations will be processed by the researchers to elicit participants' cognitive activity features. This verbalisation is recorded, transcribed, and broken down into units that can be coded via a predefined coding scheme based on theoretical assumptions about processes types involved in a particular task.

Theoretical Framework

In the 1970s, John Flavell is considered to be one of pioneers, who introduced the term metacognition corresponding to "cognition about cognitive phenomena", or simply "a thought about thought" [13]. This term has its roots in metamemory and has been developed and used in many fields based on this narrow definition. For example, throughout the evolution of this concept, cognitivists have proposed the following definitions:

- "The knowledge and control that individuals have over their own thinking and learning activities" [14].
- "Awareness of one's own thinking, content awareness of one's conceptions, active monitoring of one's cognitive processes, the attempt to regulate one's cognitive processes in relation to the learning path, and the willingness to learn as well as the application of a set of heuristics as an effective device to help people organise their problem-solving methods in general" [15].
- "Awareness and management of one's own thinking" [16].
- "The monitoring and control of thought" [17].

Currently, the term "metacognition" is commonly used to refer to thinking processes in individuals [15]. However, on the other definitions in the literature, the most mentioned definition of metacognition is "that an individual is able to bring out information about his or her cognitive structure and be able to organise it" [13, 18, 19].

In teaching and learning approaches, the ultimate goal is to enable students to learn fully through effective teacher guidance. Metacognition plays an important role in this [20]. It is strongly believed that teacher metacognition has a significant impact on the educational process and student learning [21]. H. J. Hartman [22] argues that "metacognitive teaching" is the way to maximise the effectiveness of instructional intervention. Furthermore, knowing what teachers know about how they teach should be the starting point for changes in teachers' professional development [23]. However, research on teacher metacognition has been hampered by lack of appropriate measures.

J. R. Graham et al. [24] focused on metacognitive strategies impact on writing performance. They inferred that participants who are able to make explicit what they did to plan, write, and evaluate their writing. D. Escorcia and F. Fenouillet [25] added on metacognition as positively correlated with writing performance. Learn-

ers with more awareness and information about the strategies they adopt are more likely to improve and develop other types of strategies.

In the same idea, several studies have concluded that mathematics achievement is significantly and positively related to metacognition [26, 27]. Mathematics teachers should plan their instructional content to enable learner to improve their skills in metacognitive monitoring and regulation for better problem solving [28].

Think-aloud protocol (TAP) is attached theoretically on by K. A. Ericsson and H. A. Simon [11, 29] studies, when they introduced the model of human cognition and information processing. Indeed, the human memory allows storing information with different capacities of access and storage. Namely, short-term memory has an easy access mode but a very limited storage capacity, contrary to long-term memory which can store more information but with a difficult access. Only static and conscious "states of knowledge", and not cognitive processes, can be directly referenced and reported. These knowledge levels thus become cognitive processes that considered inputs and outputs, and the information that is not currently considered.

It goes back to Wilhelm Wundt's technique of "Selbstbeobachtung" [30] (self-observation, often also called introspection). W. Wundt encouraged his participants to describe in detail their internal thoughts and experiences and to bring them to light. He saw that inner experiences are fertile ground for consciousness and that self-observation is the best way to deal with it in a given context.

Two verbal protocols types can be distinguished: simultaneous protocols, where participants verbalise during task execution (online) [31, 11, 32]. However, in retrospective protocols (offline), verbalisation occurs once the task is completed, in relatively short intervals others studies [10, 11]. Regardless the mode of the chosen protocol, it should be noted that participants may be questioned systematically throughout the activity or given complete expression freedom [33].

Three verbalisations' levels have been found to report [11]. Level 1 verbalisations are simply an internal speech result that requires no mental effort. Level 2 verbalisations include verbal encoding and the expression of internal representations. For example, verbal encoding includes a taste or movements vocalisation. At this level, only information, which participants are focused on, needs to be verbalised. Level 3 verbalisations require that you explain your thoughts, ideas, assumptions, or motivations [11].

Methodology

1. Participants

The sample involved twelve students (six males and six females) in the high school (graduation year) from four different classes in the same school. Nine teachers (five males and four females) were also from the same school but with different years of experience (between 3 and 16 years).

The participants showed their motivation towards the protocol and the years of experience was taken into account. None of the participants had prior experience of using TAP.

2. Materials

The teachers were asked to lead a learning session (4 teachers worked on a mathematics lesson and others focused on the methodology of writing argumentative text in French language). In the end, they gave to students a problem-solving situation related to what they have seen in the course. Participants were expected to verbalise their thoughts (simultaneously) while completing a cognitive task, these verbalisations were recorded, transcribed and then analysed.

3. Procedure

The study objective would be to analyse students thinking processes and their teachers during a problem-solving situation. To do so, and just before starting the protocol, following K. A. Ericsson and H. A. Simon methodological advice [11]. First of all, each participant must be informed about protocol objective as well as their role and even what the researcher expects from them (student and teacher) in order to avoid social desirability effect [10, 34, 33]. This communicative charter will ensure that the experiment runs smoothly, the participants will feel that they are in a situation where they are supposed to verbalise their thoughts and not under someone's evaluation.

Then, teachers provide a small warm-up on verbalisation, which allows participants to become familiar with this technique [10, 31, 35] and also it allows teachers to avoid large silence moments from some participants. During the experimentation, the researcher must have a repertoire of retry strategies to deal with the various obstacles encountered when the subject is verbalising. As stated by P. Vermersch [33], closed-ended questions that refer to "yes/no" responses or even every question that refers to action judgments will not be effective when the participant is making inferences or verbalisation amount is reduced. Any kind of question that leads the subject to describe his/her action is an effective prompting technique to build on what he/she says [11].

Another important point to mention is task difficulty level, which must be optimal and surmountable, allowing the participant to mobilise his/her resources in order to accomplish the requested task [33]. Finally, the main factors to consider for a successful protocol are the precision of the instructions and their reminders, the pre-training of the participants, the acquisition of effective reminder techniques and the difficulty of the task.

Our originality part in this study is to analyse teachers' thoughts (4 of math and 5 of French) [36] during two lessons (one for each discipline) while asking their students to say what they think during the resolution of a problem situation proposed by their teachers) [36] and which is obviously related to the lesson presented.

French teachers will present a lesson on writing an argumentative text methodology and they will ask their students to write a 20-line text. In the same way, for the math teachers they will present a lesson on numerical sequences and then they will give them an exercise of five questions with progressive difficulties. We note that the two sessions last an hour and a half and 45 minutes for the task requested.

After data collection, each of the participants' verbalisations was transcribed and submitted to a protocol analysis by three researchers (PhD students) [11]. An inter-rater agreement score of 0.85 was reached and, according to Burla et al. [37] guidelines, this level of agreement is considered "perfect".

First, we tried to relate the actions performed by the participants to their verbalisations. Second, we developed a primary coding system based on J. D. Bransford & B. S. Stein [38] problem-solving model for students and the nine-dimensional model of teacher reflection by P. Zwozdiak-Myer [39] as well as the coding and theorising stages (SCAT). This system was adapted to the verbalisations collected from the participants, adding the emotional dimension that is considered important in our study object [40].

4. Coding system

This research focused on the coding and theorising steps (SCAT), which was developed as a method for qualitative data analysis by T. Otani [41]. It is a method that allows even beginners in qualitative research to relatively and easily analyse textual data according to the following steps:

Obtain textual data through interviews, questionnaires or other surveys.

1. Develop the coding:

a. Note interesting phrases in the textual data.

b. Rephrase words from the previous section with words that are not in the original text.

c. Complete the concept, phrase or sentence that explains the previous paragraph.

d. Based on "a" and "b" list of the selected themes.

e. Discuss, note questions, problems, and assumptions to consider.

2. Create a storyline, once all the data from the interview is coded, link the topics you entered in "d" and write them down as a text that summarises the interview.

3. Continue the description, then analyse and complete the predictions and hypotheses you can imagine from the original textual data in detail.

4. Note the questions and issues and identify those that need further investigation.

Table 1

Themes, description and coding of actions during TAP among students

Theme	Description	Coding	Examples provided by the participant
Description of task (problems, objective, constraints)	Identify the problem and define one or more objectives to achieve it, taking into account the constraints and obstacles	Facilitating: Leads to a correct problem resolution Non-facilitating: Does not lead to a correct problem resolution	"… Well, we have to write an argumentative text … I have to think about arguments and then how I have to integrate them into the text … "
Development of mental schemas (inferences, detailed representations…)	Knowing how the participant's view of what is being asked can impact their action	Facilitating: Leads to a correct problem resolution Non-facilitating: Does not lead to a correct problem resolution	"… The exercise includes five questions that should not take long to solve given the time allotted for the exercise … "
Emotions and selective attention	Perception and feel of familiarity with the problem	Facilitating: Leads to a correct problem resolution Non-facilitating: Does not lead to a correct problem resolution	"… I don't feel stressed … I feel that I am able to answer all the questions correctly … I had to apply the rules given in the course … "
Solution planning	Procedures and steps taken to solve the problem	Facilitating: Leads to a correct problem resolution Non-facilitating: Does not lead to a correct problem resolution	"… First, I have to remember all the rules we saw in the course and write them on the draft, then I start with the easiest question … "
Results prediction (performance)	Monitoring of action during problem solving	Positive: Promotes more metacognitive control Negative: Does not promote metacognitive control	"… I'm not sure, I think 80% of my answers are right … I think I have done all I can … I am waiting for the correction to make sure about some things … "
Decision-making and performance evaluation	Goal attainment and performance judgments for the future	Facilitating: Leads to a correct problem resolution Non-facilitating: Does not lead to a correct problem resolution	"Je pense que j'ai fait tout ce que je peux … j'attends la correction pour que m'assure sur certaines choses …"

Table 2

Themes, description and coding of events during the TAP among teachers

Theme	Description	Coding	Examples provided by the participant
Preliminary analysis of the task	Knowledge about the task and identification of invariant cues	Effective: Allows the student to learn better and more Ineffective: Does not allow the student to learn better and more	"So … after the oral activity we had on managing a debate … In the same vein, today we're going to try to learn how to argue our ideas in a 20-line text"
Students' knowledge	Examine how students think	Effective: Allows the student to learn better and more Ineffective: Does not allow the student to learn better and more	"… I try to categorise my students according to their abilities … the nature of the task requires a specific method or approach to tackle it"
Emotional regulation mechanism	How the teacher controls and regulates emotions	Effective: Allows the student to learn better and more Ineffective: Does not allow the student to learn better and more	"… some inappropriate behaviors of my students (whispering, indifference) do not reflect my efforts, which makes me disappointed … "
Attitudes during the session	Judgments about professional behaviors and actions	Effective: Allows the student to learn better and more Ineffective: Does not allow the student to learn better and more	"… I pay attention to my voice … I move around the classroom to arouse my students … I try to see the general climate of the classroom and react accordingly … "
Development of a conceptualisation system of professional activities	Anticipatory and feedback strategies used to challenge professional practices	Effective: Allows the student to learn better and more Ineffective: Does not allow the student to learn better and more	"I like to ask implicit questions to find out what they think about the session … "

We tried to respect the methodological norms related to qualitative protocols, especially those mentioned by Y. S. Lincoln et al. [42]: credibility, transferability, reliability and confirmability.

Regarding credibility, a triangular analysis was carried out in this study, in which the data were processed by three researchers independently and compared at the end of this stage. In addition, an expert in qualitative studies was brought in to assist us throughout the data collection and analysis process.

The purposive sampling method chosen as well as showing how the data were coded enhanced study transferability. Second, each session was conducted under the same conditions, with the data analysed and coded by all three researchers systematically to ensure reliability of our results. Finally, the transcripts and codlings were kept to respect confirmability principle.

Results

To meet our research objective, students were divided into three groups (for each task type) according to their performance in solving a problem situation as well as the verbalisations made during this task.

The first group for the math exercise includes those, who have a 100% correct answer; the second are those, who have answered well but made a calculation error mistake and the third group are the students, who give an incorrect answer.

Table 3

Modelling student performance during problem solving (Math)

Group	Number of participant (students)	Percentage
Correct answer	7	58,33%
Incorrect numerical application	2	16,66%
Incorrect answer	3	25%

We can notice from the above table (Table 3) that 58.33% of students answered correctly to the math exercise, while about 42% did not succeed due to incorrect numerical applications (16.33%) or a problem with the strategies used to solve the problem (25%).

As we can observe in Table 4, participants who made incorrect numerical applications were due to haste or poor time management, which allowed them to either make trivial mistakes or simply forget to do it. For those who had an incorrect answer, it was due to a deficit in working memory and/or related to stress or fear of failure or they are unable to answer what is asked.

Table 4

Type of error for group 2 and 3 (Math)

Group	Type of error	Examples provided by the participant
Incorrect numerical application	He rushes when he wants to do the calculation	"... so 28 out of 2 equals 14 ... I will write ... now I go to the second question"
	Leaves the calculation until the end of the allotted time or just forgets to do it	"In order not to make mistakes I'll leave the calculations until the end ... oh lala I have to be quick I have 5 minutes left ... "
Incorrect answer	Difficulty remembering (memory)	"... I feel that the rule is at the end of my long ... I can't remember it's serious ... "
	Stress or fear of failure	"... I have to answer this question... it's an easy question ... otherwise how am I going to do for the other courses that are more difficult ... I'm starting to sweat it's not great at all ... "
	Can't solve the exercise	"... I can't really do it, just the first one was easy ... the other questions I don't know what to do ... "

Regarding writing exercise, the first group was those who wrote well and followed instructions, while other students were able to write but did not follow the instructions. Finally, those who did not manage to finish the essay are in the third group. Table 6 shows in detail the errors made by the students of group 2 and 3.

The results (Table 5) showed that 50% of the students wrote well according to the instructions. However, the other half had a problem understanding what was asked (16.33%) or they could not finish the essay (33.33%).

Table 5

Modelling student performance during the resolution of a problem situation (Writing a text)

Group	Number of participant (students)	Percentage
Good writing (following instructions, use of logical connectors, etc.)	6	50%
Writing without respecting the instructions	2	16,66%
Incomplete writing	4	33,33%

Table 6 shows error type produced by second and third group students during the writing of a 20-line argumentative text. In fact, those who were able to write the text without respecting methodological instructions either manage to define the purpose of the task or lack knowledge related to the use of logical connectors. The same is true for the group that did not complete the essay due to poor time and resource management and a lack of vocabulary in the French language.

Table 6

Error type for group 2 and 3 (Writing a text)

Group	Type of error	Examples provided by the participant
Writing without following instructions	No use of logical connectors	"… I now move on to present the counter-arguments … I put dots and skip the line so that I differentiate between the first argument and the second one … "
	Undefined objective	"I will leave my point of view until the conclusion … so I will have something to write in this part … "
Group	Lack of vocabulary	"It's a very difficult task … I have the ideas in my head … but I don't know how I'll express them in French"
	Poor time and resource management	"Ohlala … I have a lot left in the development and I haven't started the conclusion yet … I won't be able to finish the hour … "

With regard to teachers, the first group includes the participants who focused only on getting the students to do the work, while others created a reactive and favourable climate where the students interacted and collaborated. The last group is dedicated to those who monopolise the floor during the session.

33.33% of the teachers were focused on the student and his/her activation during the session, two teachers ensured that their students were involved and interactive with a percentage of 22.22%. Nevertheless, 44.44% focused only on their speech (Table 7).

Table 7

Modelling the intervention of teachers during an educational lesson

Group	Number of participant (students)	Percentage
Student activation	3	33,33%
Student engagement and interactivity (note taking, group work …)	2	22,22%
Monopolisation of speech	4	44,44%

It should be noted that the modelling of the teacher' intervention was done in terms of dominance in relation to the three axes of pedagogical intervention (student activation, student involvement, engagement and interactivity, and monopolisation of the floor).

Based on the verbalisations of the teachers as well as their feedback, we can say that their attitudes were conditioned by the pedagogical support used (as an example power point presentation):

Teacher 1: "… can you see the slide well? … Okay, who can tell us what we saw in the previous slide?".

Teacher 5: "… I need to see did they like the explainer video or not … Maybe I need to watch it again so they understand better … ".

Others tend to behave according to the general climate of the class, i.e. how students react to what is offered as instructional content. As an example:

Teacher 4: "… I know my students, the looks on their faces mean they didn't understand even that silence … I don't know maybe the situation at the start seems out of reach".

Teacher 1: "… there is a lot of noise, it means that the lesson does not interest them … or it is too easy … maybe I will try to rectify the instruction … ".

Then, the second group of participants insisted on the student's involvement in the whole teaching-learning process, considering him/her as the centre of the pedagogical act. Examples are illustrated in this sense:

Teacher 9: "… then you are led to tell me what is an argument … you don't worry … we will make a mind map where all the answers are correct and that can help us have our own definition".

Teacher 8: "… Now we are going to form groups by affinity and you have to put in a table as many arguments for and against … The group that gives more arguments will have a bonus … ".

Finally, the last group contains teachers who prefer to have a total control of the session, following a pre-established scenario without showing any flexibility:

Teacher 2: " …. Come on we have to be quick…we have one more game before we finish the class … write quickly … ".

Teacher 3: "… I repeat a second time … the most important thing is to have a well-structured and well-organised flow of ideas … after that the writing will be easy to do …".

Discussion

We recall that our research objective is to discover the key elements of a cognitive process related to the problem situation. For this purpose, we opted for the protocol of thinking aloud intended for teachers on the one hand during animation of a lesson and their students on the other hand in the realisation of a learning activity.

Our first results also concern participants who answered the math exercise, a good part of which gave an incorrect answer (43%), due to a short-term memory disorder, an emotional factor (stress or fear of failure) or an incorrect problem-solving process.

This is confirmed by A. Dietrich [43], who reports that short-term memory provides access to relevant information to solve a particular problem; another research has linked it to the ability to maintain attention on the task with good time management [44]. In relation to math, positive relationships between short-term memory and various types of problem solving have been concluded by several researchers [45, 46]. Indeed, poor long-term memory may lead the learner to develop incorrect inferences and subsequently incorrect solution strategies.

M. H. Ashcraft and J. A. Krause [47] mention that interference from negative emotions namely stress and anxiety are considered indicators of negative math outcomes. According to the attentional control theory by M. W. Eysenck and N. Derakshan [48], these negative emotions negatively affect learner's ability to control his/her attention and consequently a difficulty in engaging his/her cognitive resources in solving the problem situation. Cruz Neri et al. [49] insist on careful reading exercises before starting the answering process, also motivation in mathematics is seen as an indispensable factor for a better performance.

However, problem complexity situation can become a source of stress that guilt individual cognitive functions during the completion of an exercise in math [50]. In the same sense, using digital support in math instruction can yield impressive results [51]. Certainly, studies have shown that programming develops the student's mathematical thinking and allows a better understanding of certain concepts related to geometry and algebra [50] or similarly the possibility of implementing a digital textbook would be an asset [52]. In relation to working memory and math performance, J. Holmes and J. W. Adams found that there is not a direct impact but often related to mental arithmetic and many other mental and metacognitive abilities [53].

Our second result concerns students who wrote a 20-line argumentative text. Certainly, half of the participants succeeded in their task and effectively met the success criteria of the pedagogical situation. While four participants (44.44%) could not complete the writing either because of poor time management or lack of extensive vocabulary and two others (16.66%) did not write correctly because of non-clarification of the objective or use of logical connectors.

According to L. R. Hayes [54], writing is considered a complex problem-solving activity in which the intervention of metacognition is important [55]. Vocabulary is

an important factor in learning to write a foreign language [56], which can only have an impact in the presence of relevant and effective strategy instruction as cited in the model by S. Harris and K. R. Graham's [57]. Indeed, Rietdijk S. et al. [58] proposed four factors of writing instruction including goal setting, peer support, feedback as well as writing strategy instruction. In addition, the most successful learners are those who are aware of their deployed strategies, something that will enable them to develop the skills of planning, writing, and revising [59].

Nevertheless, other researchers have focused on other techniques and metacognitive methods of developing learner's writing competence namely reflective journaling [60, 61], which is a tool to help the learner to be more aware in the learning process in order to choose the appropriate strategies for the situation or to develop their repertoire of cognitive and metacognitive strategies. In addition to this, studies on foreign language writing learning have proposed other digital techniques namely "Digital Storytelling" [62, 63]. It helps develop their creativity skills, use vocabulary and grammar accurately, and write sentences correctly.

Our third result focused on teachers' verbalisations yielded interesting results. Indeed, the collected verbalisations converge on three main aspects: Student Activation, Student Involvement, Engagement and Interactivity, and Monopolisation of Speech, but with different percentages.

Based on the study by C. E. Wolff et al. [64], expert teachers were more able to manage the class well and subsequently anticipate any kind of unpredictable events. Similarly for B. K. Morris-Rotschild and M. R. Brassard [65], inexperienced teachers are more able to show more creativity and commitment in planning a learning session but on the other hand they show less effectiveness when it comes to managing some particular situation especially with learners. With regard to teacher attitudes, those who find it difficult to make their professional practices explicit, will have difficulty intervening effectively and may either talk too much to explain or inhibit the crucial role of the learner as an active participant in his/her learning [66].

However, the need for a structured continuing professional development programme that addresses all the constraints encountered can negatively impact the teacher's instructional intervention [67]. This continuity, which is the subject of consensus among authors, gives rise to the idea that the teaching profession is constantly changing [68]. Another important point is teachers' satisfaction with their job [69], which must be constantly monitored through factors such as: supervision, colleagues, working conditions, salary, responsibility, the job itself, promotion, safety, recognition and many other factors [70].

Conclusion

The think-aloud protocol remains a very rich tool in terms of data, constitutes a fertile ground allowing to have an idea on the individual's thinking process in order to analyse and develop it for a better performance. However, it is a difficult method to apply and requires a set of methodological precautions to be respected in a very rigorous way.

The more one digs into the research, the more one enters into the complexity required by all the sciences that surround the educational act. There is no model of the learner's behaviour, but it is possible to include certain characteristics that concern his/her reflection for a better understanding and pedagogical intervention. Therefore, the role of the teacher remains important in the sense that he/she must optimise the learner's abilities and orient them towards learning and the development of cognitive and metacognitive skills. It is worth noting that the biological traits of both students and teachers, including their circadian rhythm, can significantly influence an individual's cognitive performances [71], which may be the subject of future research.

Some limitations of our research seem to be mentioned. Indeed, we chose students of the same level and from the same school. Moreover, teachers who participated in this study show more or less similar characteristics and so we would have had to think about other criteria. So, these highlighted elements constitute limitations that can be overcome in future research.

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***Conflict of interest statement*.** The authors declare that there is no conflict of interest.

Received 29.12.2022; revised 15.03.2023; accepted for publication 05.04.2023.
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Информация о конфликте интересов. Авторы заявляют об отсутствии конфликта интересов.

Статья поступила в редакцию 29.12.2022; поступила после рецензирования 15.03.2023; принята к публикации 05.04.2023.
Авторы прочитали и одобрили окончательный вариант рукописи.

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Información sobre conflicto de intereses. Los autores declaran no tener conflictos de intereses.

El artículo fue recibido por los editores el 29/12/2022; recepción efectuada después de la revisión el 15/03/2023; aceptado para su publicación el 05/04/2023.
Los autores leyeron y aprobaron la versión final del manuscrito.