

THE TACIT-EXPLICIT DYNAMIC IN LEARNING PROCESSES

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In this report we present the methodology used in a study that investigated the tacit-explicit dynamic in learning processes. We have analyzed an episode related to a discussion about the difference between plane figures and spatial figures promoted by the teacher in her mathematics classroom (the students are aged 11 to 12). The data analysis was based on some aspects of Polanyi's theory on tacit knowledge, and benefited from a variation of the 'graph-theoretical model for the structure of an argument' developed by Strom, Kemeny, Lehrer and Forman. The methodology employed exhibited a strong indication that the lack of correspondence between what the students are uttering and their original understandings is related to the tacit-explicit dimension.

INTRODUCTION

In a recent study Frade and Borges (2002) analyzed some current curricular goals in the light of Ernest's (1998b) model of mathematical knowledge, according to its mainly explicit and mainly tacit components. The materials examined were suggested by curricular documentations from several countries and at different levels of teaching. The analysis showed the prevalence of the mainly tacit components over the mainly explicit in such curricular goals.

Since then, we have been working on this subject aiming at a better understanding of the tacit dimension of mathematics teaching and learning. Throughout our process of investigation we found different references to Polanyi's (1962, 1969, 1983) concept of tacit knowledge. Fischbein (1989), Tirosh (1994) and Sternberg's (1995) researches address what can be called 'Polanyi's psychological version of tacit knowledge': knowledge that functions as subsidiary to the acquisition of other knowledge. On the other hand, Ernest (1998a,b) and Wenger (1998), for example, use the words 'tacit' and 'explicit' as opposites to refer to different, but complementary dimensions of the same component of a certain practice. Whatever the case, the above-mentioned authors share in some way Polanyi's epistemological thesis that all knowledge is tacit or constructed from tacit knowledge (Polanyi, 1969).

In this report we present the methodology employed in the analysis of an episode related to a discussion about the difference between plane figures and spatial figures, promoted by the teacher in her mathematics classroom (the students are aged 11 to 12). Such analysis benefited from a variation of the 'graph-theoretical model for the structure of an argument' developed by Strom, Kemeny, Lehrer and Forman (2001) to integrate those two above-mentioning meanings of the concept of tacit knowledge with other important element of Polanyi's theory: the three areas or domains – ineffable, intermediary and sophistication – in which the relation between thought and speech varies from one extreme: tacit prevailing over the explicit, to another:



tacit and explicit falling apart, moving through an intermediary level: tacit corresponding to the meaning of speech (Polanyi, 1962, p.87). This integration allowed us not only to investigate the types of knowledge – mainly explicit or mainly tacit – the students used in a ‘psychological way’ to perform the task of elaborating an understanding of the difference between plane and spatial figures, but mainly how much the projection of those types of knowledge on the task were manifest tacitly or formalized by the students. Some results of the research are presented.

DEVELOPMENT AND METHODOLOGY

Initially, the students were asked to elaborate and present their understanding in writing (this was considered as task 1). To this end, they had to observe a classifying table – flat, plane, volumeless forms *versus* spatial forms that can have a volume – proposed in their textbook. This table had solely pictures. After some time, the teacher conducted a conversation about the students’ understanding of the difference between plane and spatial figures. When the conversation began, some students manifested difficulty in putting their understandings in writing. So, the teacher let them elaborate such understandings orally in real time (this was considered as task 2).

The episode lasted for twenty minutes and was recorded on tapes, which were transcribed entirely. After examining the data categories were established to account for: 1) students’ knowledge used in a subsidiary way to perform and control of the task, 2) students’ internal articulation that preceded their utterances, 3) the teacher’s interventions, 4) two other non-fully observable processes: concentration (observation of the classifying table by students) and shifting of focus (not recognition of some knowledge as instruments by the students). Below I illustrate the categories.

1. Students’ tacit knowledge (related to the task in question)

C1: Surfaces

Example: “...in some figures **there are some flat forms that make** a figure with a volume. Example, the **cylinder** has two **faces** with the form of a **circle**, the **prism** has two **faces** of one **hexagon** and two faces of a **rectangle**.” (task 1)

C2: Capacity

Example: “The difference between the flat, the plan and without volume and the spatial figures that can have a volume is that the flat ones **cannot hold material inside** and the ones which have volume **can hold material inside**.” (task 1)

C3: Width

Example: “This one is **hollow inside** and this one **is not hollow inside**”. (task 1)

C4: Rigid movement

Example: “...if you take one of these triangles and **take it from the paper page** it will be just like the page; you **turn it** and it is all the same. Now, this one will be like a

pencil, you **turn it** and **it shows other angles of vision**. I think that's the main difference.” (task 2)

C5: Bending

Example: “We put here that the figures without volume **do not stand** and the spatial figures **do**.” (task 1)

C6: Tangible reality

Example: “This ones (referring to spatial figures) **are real things** and **those ones are papers** (referring to plan figures)”. (task 2)

C7: Meta-cognition

Example: “Ah, I **more or less understood** what some of them are”. (task 2)

The words or expressions in bold in those utterances indicate our identification of the clues the students gave about the knowledge they were using in a subsidiary way to elaborate an understanding of the difference between plane and spatial figures. The categories were named according to this knowledge. This does not mean that the students were conscious of having that knowledge or even that some of those types of knowledge stood as formalized mathematical knowledge. Also we do not state affirmatively what the origin of that knowledge was: school instruction, informal acquisition through daily life experience, or germinal mathematical ideas. We have interpreted the above-mentioned knowledge C1, C2,...,C6 as mathematical because they were used tacitly or instrumentally for a mathematics task. Besides, it is possible that in the future that knowledge can be formalized mathematically allowing the students to take them as mathematical knowledge.

Task 1 in parenthesis indicates that the student was reading what he/she wrote. Task 2 in parenthesis indicates that the student was elaborating his/her understanding in real time.

2. Students' internal articulation of the understandings produced

E1: Priority of tacit - identified with Polanyi's ineffable domain of co-operation between tacit (personal) and explicit (formal). E1 indicates an internal articulation, which was not projected in speech or else was projected vaguely and not precisely. Examples of utterances that we have interpreted as resulting from E1:

“It's the word that doesn't come out”. (task 1)

“It's like a piece of paper, you turn it that's all it has”. (task 2)

E2: Tacit on the borderline with the explicit. E2 indicates an internal articulation which was progressively projected in speech in such a way that the tacit seemed to be close to the explicit. Example:

“Look here, all the spatial forms that have volume give an example of being real. And to be real (some hesitation) look at a prism, for example, of a hexagon. You connect a hexagon to another with rectangles you have a prism”. (task 2)

E3: Tacit coincides with explicit - identified with Polanyi's intermediary domain of co-operation between tacit and explicit. E3 indicates an internal articulation, which was fully, and exactly projected in speech. Example:

“We put here that the figures without volume do not stand and the spatial figures do”.
(task 1)

E4: Explicit separate from tacit - identified with Polanyi's sophistication domain of co-operation between tacit and explicit. E4 indicates an internal articulation which was not reflected in speech. In this case, although the speech was confident and with no hesitation, it was incoherent or contradictory. Example:

“The forms without volume can only be seen in one way, they are plane and flat. The forms with volume can be seen in many ways, almost all of them are solid and have a volume”. (task 1)

E5: Explicit under check. E5 indicates an internal articulation, which results from the students mobilizing his/her meta-cognition. The student performed the task but doubted the relation between his/her internal articulation and its external representation. Examples:

“I wrote here, but I don't know if it is correct”. (task 1)

“What is this?! The hexagon has the surface that has the base for, the base?!” (task 1)

Those categories were built in the following way: from the original records and their transcriptions we searched for students' utterances excerpts, which could be interpreted as a result of their *modus operandi*. On the other hand, each internal articulation identified would be preceded by the mobilization of specific tacit knowledge, which made up students' understandings.

3. Teacher's interventions

I1: Commands

Example: “Now, you all must observe the classifying table for some time and then write the difference between ...”

I2: Guiding the speeches

Example: “And you Peter, what about the difference between...?”

I3: Explaining

Example: “This doesn't have to be right, it is your perception.”

I4: Demanding explanation

Example: “What do you mean by...?”

I5: Posing question

Example: “There is more to it. Can't you see anything else?”

I6: Listening

Example: “Go on”

The teacher's mental actions were not examined in this research to avoid more risk of interpretation and because the focus of the analysis was the students' learning processes.

4. Two other non-fully observable processes

O: Concentration, which corresponds to the students' observation of the classifying table, and SF: Shifting of focus, which corresponds to an interruption of the students' performance due to an unfamiliar feeling with the instruments that they or their classmates had used to complete the task.

THE GRAPHIC REPRESENTATION OF THE DATA

Once those groups of categories were constructed, we divided the episode into five segments where each of them was represented by a graph (e.g, graph 1 corresponds to segment 1, and so on). The idea of the graphs came from the work by Strom et al (2001), and was intended to exhibit the tacit-explicit dynamic of the episode.

In each graph (refer to table 1 as an example of all graphs) the categories were disposed in a circle and oriented flows were drawn to represent the dynamic among such categories (or the structure of the actions produced during the event). From each graph the episode was, then, re-analyzed.

Continuous flows (straight lines) represent the observable aspects of the episode: the students' and the teacher's utterances. Interrupted flows (dotted lines) represent non-observable aspects. For example, in the graph 1, the continuous flow number 11, which departs from I2 toward C7 corresponds to an utterance of the teacher (observable aspect) to a student, and resulting from an intervention of the type I2: Guiding the speech. This teacher's utterance, in its turn, provoked in that student or in another student the mobilization of his/her tacit knowledge of the type C7. The next flow – number 12 – in dotted line, indicates that the student attributed meaning to and integrated such knowledge (non-observable aspect) producing an internal articulation about his/her understanding of the difference between plane and spatial figures, which was not projected in his/her utterance or was projected vaguely and non-precisely (in the former, although the student had produced an utterance it did not project any clue about his/her understanding of the difference between plane and spatial figures). This utterance (observable aspect) was then originated from E1 and was represented by the flow number 13 in straight line.

The darker flows correspond to the students' actions in relation to task 1. For example, the flow number 34, which departs from E3 toward MF, corresponds to a student's utterance resulting from his/her articulation of the type E3: an internal articulation that was fully and exactly projected in his utterance, and answering the task 1. The orientation of that flow shows that this utterance provoked in him/her or in another student a shifting of focus. Following, the flow number 35 indicates that such a shifting of focus led a student to produce an articulation of the type E5, that is, an internal articulation that put the explicit under check. The utterance resulting from

this articulation was represented by the flow number 36. All of this related to the task 1. On the other hand, the lighter flows correspond to: (a) the students' actions in relation to task 2 (for example, the flow number 44 that departs from C2 toward E3, and the flow 45 that departs from E3 toward I6); (b) the teacher's utterances (for example, the flow number 18 that departs from I6 towards C7).

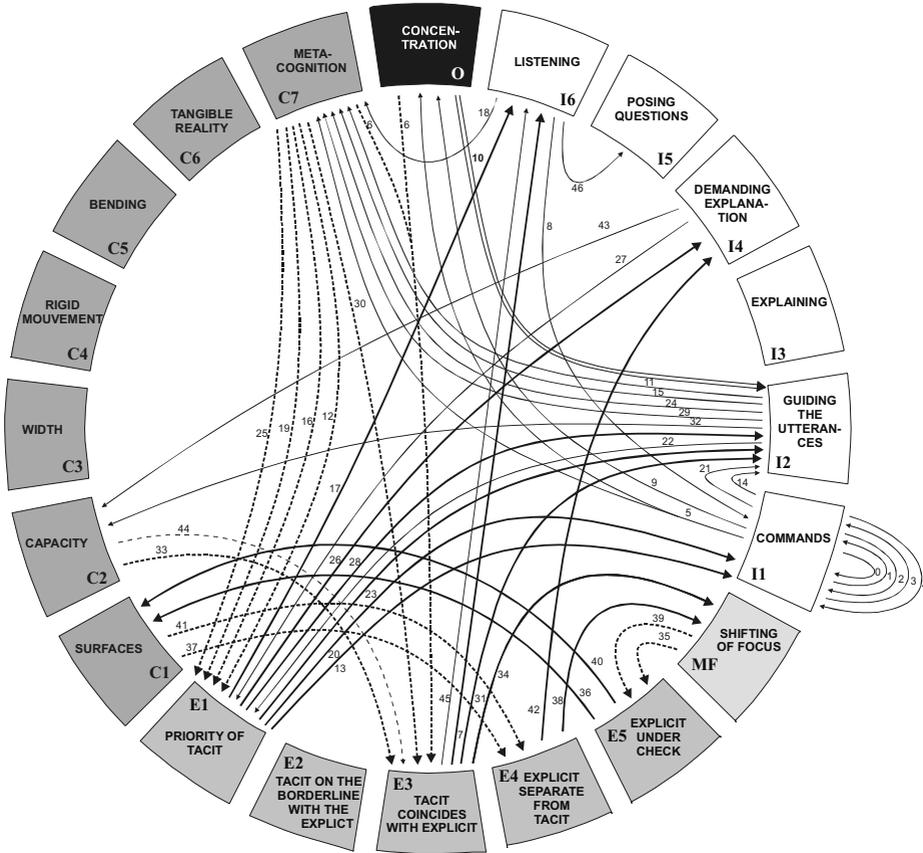


Table 1: Graph 1

The numbers given to the flows correspond to the chronological sequence of the episode in the record's transcription or to the chronological sequence of the meanings produced along the event.

From the observation of the behavior of the flows in each graph, we tried to understand the characteristics of the corresponding segment. When we perceived some regularity or some interesting behavior of the flows (as for example, great

concentration of flows in some specific category), we turned to the record or to its transcription to interpret them.

We would like to observe that students' tacit knowledge about width (C3), rigid movement (C4), bending (C5) and tangible reality (C6) were not identified in segment 1 of the episode. The same can be said in relation to the internal articulation E2, and teacher's intervention of the type I3. That is the reason that we do not find flows departing from those categories. They were identified in subsequent segments whose graphs, due to lack of space, will not be presented in this report.

The two main differences between Strom et al's graphs and the graphs in the above-mentioned analysis are: (a) more distance between the observable and non-observable aspects of our categories than in theirs: our inferences were of a higher order, in the sense that they demanded more interpretative effort and riskier evaluation; (b) the flows of our analysis, except number 10, represent more than the chronological sequence of the meanings produced along the event: they correspond precisely to the students' and the teacher's utterances.

FINAL COMMENTS

Concerning the mathematical task under investigation, the methodology demonstrated: (a) the students' knowledge used in a subsidiary way; (b) how the tacit co-operated with the explicit in the projection of that knowledge on the task; (c) evidence of the concentration process (*indwelling*, Polanyi, 1983) shifting of focus and detailing of the particulars of tacit knowledge (Polanyi, 1962, 1983); (d) that, among the various types of tacit knowledge used by the students to accomplish their tasks are the mainly explicit and mainly tacit components of Ernest's (1998b) model of mathematical knowledge.

More precisely, the following components of the model identified were: (1) knowledge related to surfaces of solids: prism, cylinder, hexagon and rectangle, for example, which are included in the mainly explicit component 'statements and propositions'; (2) ontological concept of plane and spatial figures, which is included in the mainly tacit component 'meta-mathematics views'; (3) aspects of oral language, which is a mainly tacit component.

An interesting result that emerged from the analysis is related to the perspective of cognition not necessarily restrict and coincident with language, but seen as a situated social practice, moving between the poles of the tacit – effective action – and the explicit – intersubjective projection of such an action – dimensions. The analysis suggested that student's answer to an oral task may be apparently mistaken under the viewpoint of the discipline. This does not necessarily mean that he/she does not know the correct answer, or else that he/she had not interiorized certain types of knowledge. The presumed mistake or non-interiorization may indicate that, when uttering his/her understanding, the student could be operating either in the ineffable (E1) or in the sophistication domain (E4). If in the former, his/her tacit knowledge was still under construction and therefore predominant over the explicit. This results

in a type of ‘painful’ utterance, which provides vague clues, thus not enough for us to identify the student’s understanding. If in the latter, the tacit functioning of the student’s thinking could have been blocked due to some speech ineptitude: the student’s symbolic operations seemed not yet ready to express his/her understanding. As a result, his/her utterance is filled with imprecision or contradiction, although produced confidently and with no hesitation.

Exercising her sensibility to understand the student’s *modus operandi* through the categories proposed in this analysis can help the teacher identify which stage of learning – tacit prevailing over the explicit, tacit on the borderline of the explicit, tacit and explicit coinciding or tacit and explicit independent – the student is in. Depending on the stage identified, the teacher can create pedagogical supports to promote practices of conversation to help students align, as much as possible, their internal articulation to the domain in which the tacit and the explicit coincide. This is fundamental in the processes of formalization and social communication of the student’s mathematical knowledge.

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