FaSMEd

Raising Achievement through Formative Assessment in Science and Mathematics Education

Time-temperature graph as a boundary object in Maths and Science

Subject:	Mathematics & Science
Age of students:	12 - 13 years
Hardware:	Clickers, teacher PC, micro-document camera, projector
Software:	*Je lève la main* (student response system)
Functionalities:	Sending & displaying, processing & analysing
Time:	10 lessons of 1 hour each
FaSMEd partner:	Ecole Normale Supérieure de Lyon
Short Abstract:	This sequence aims at correctly interpreting the time-temperature graph during a change of state. The process of formative assessment relies essentially on different quizzes proposed by the teacher to collect and analyse student achievement, as well as on individual and personalised work.

1. Content

Time-distance activity is implemented in mathematics and seen as a preparation for the physical study of the variation of the temperature of water over time during a change of state. In this physical context, the time-distance activity has been adapted as a "time-temperature" activity. More precisely, the interdisciplinary work between mathematics and physics is carried out within the science chapter called "Characteristic magnitudes of water". The general goal of the interdisciplinary learning sequence is working on the notions of magnitude, unit and measuring device. In particular, the study focuses on magnitudes characterising water: temperature (of change of state), mass and volume (volumetric mass). The main difficulties detected by the teachers within this sequence are:

- defining magnitudes and distinguishing them from units;
- definition the mass;
- distinguishing mass and volume.

2. Activity

2.1 Aims

Specifically, the learning objectives of the mathematics lessons, within this sequence, are:

- Classifying integers.
- Constructing a graph and reading information on it: magnitudes on axis, scale, evolution curve.
- Associating units with the corresponding magnitudes (and measuring device).
- Magnitude and unit: calculating/measuring a volume.

The learning objectives of the science lessons, within this sequence, are:

- Associating units with the corresponding magnitudes (and measuring device).
- Reading mass and volume measures.
- Practising an experimental process for highlighting how mass and volume behaves during a change of state.
- Detecting a temperature using a thermometer or a sensor.
- Realising, observing, schematising experiences of change of state.
- Constructing the graph that corresponds to a change of state, verifying and exploiting the results.

2.2 Structure / Methodology

First lesson (maths)

The objective is detecting students' state of knowledge about the coordinate plane and representations of data (tables, graphs, charts, ...).

Two multiple choice tests (see "t-T-lesson1-quiz1" and "t-T-lesson1-quiz2", and related EN versions) are proposed in the classroom: students answer individually to each question with their clicker; the teacher does not comment the results on the spot but stores them in the memory of the computer for further analysis.

Second lesson (maths)

The objective is understanding students' interpretations of a time-distance graph.

The activities "Journey to the bus stop" and "Matching a graph to a story" (see "t-T-lesson2&3-activity") are proposed in the classroom: the teacher organises the lesson with a first individual work where students have to think alone to a story that can fit the graph. Thereafter students work by groups; within each group, the teacher designates a spokesperson who has to take notes on the group answer. The group session ends with a pooling of ideas and interpretations. Possible misinterpretations, like "The path is climbing" or "Tom turns on his right", show that the graph is interpreted as a map and the line is seen as Tom's trajectory instead of the representation of the distance to the house as a function of time.

Third lesson (maths)

The objective is understanding students' interpretations of a graph in different contexts.

The teacher revises the activities of the previous lesson with the students, by projecting the text and commenting the results. Then, he proposes to students the next activities (see "t-T-lesson2&3-activity").

For each activity, students are organised in groups of 4 students: they work individually in paper and pencil for about 10 minutes and then they discuss their answers in the group. The teacher walks through the classroom and checks what the students write, sharing students' doubts and questions with the whole class. Finally the teacher lead the pooling of all of the students' responses.

Several difficulties can emerge:

- the meaning of the given table of values;
- the meaning of a graphical representation;
- the number of curves to be drawn;
- the axis definition;
- the identification of the extreme values in the table for deducing the range and eventually the scale of the graduation.

The teacher discusses and validates the scale with the students and he provides them with graph paper with graduated axis.

Fourth lesson (physics)

The objectives are carrying out an experiment and following an experimental protocol.

Students have to realise an experiment of water solidification and to collect data. The title of the lesson is a question: "How is it possible to know if the achromatic liquid in the test tube is water?". The first work that the teacher asks to her students is to write a hypothesis; after a questions-answers phase, she writes on the whiteboard: "If the achromatic liquid in the test tube is water, then the freezing point is 0°C."

The class is divided into groups of three students by lab bench. They have to collect the temperature of the water at regular intervals while placing the test tube with the achromatic liquid in the cooling mixture. The protocol of the experiment is given by the teacher.

In order to illustrate the experiment, she shows a simulation on the computer, explaining the different components needed and the first steps of the experiment. Students have to draw a detailed schema of the experiment. The teacher gives the cooling mixture (ice and salt) and the students begin the experiment.

Fifth lesson (maths)

The objective is the construction of the graph of the temperature as a function of time, starting from the data collected by the students during the previous session.

The teacher requires students (see "t-T-lesson5-activity") to draw the curve of the evolution of the temperatures coming from the simulation software and that coming from their own data.

Sixth lesson (physics)

The objective is analysing a graph, in terms of increasing and decreasing temperature and temperature plateau during a change of state. Both the physics and the mathematics teachers are present participate in the moments of classroom discussion.

The first task of "t-T-lesson6&7-activity", that students have to solve for homework, is revised in the classroom through a quiz. The teacher has prepared one multiple choice question where she proposes three stories for explaining the given graph. Students have to choose, through the student response system, which story is more similar to their story.

The teacher displays immediately the graph of the results and discusses with the students some keywords of the stories: "regularly", "instantaneously", making reference to the practical experiment that they have done during session 4.

The task 2 of "t-T-lesson6&7-activity" is then introduced by the teacher for verifying students' understanding of the previous activity. Students have to work in group of 3 to find the story that matches the given graph. For collecting all of the students' answers, the teacher askes students to type their answer individually on their clicker. She shows immediately the results to comment them with the class.

Seventh lesson (physics)

The objectives are reading, analysing and interpreting a change of state graph.

The task 3 of "t-T-lesson6&7-activity" is an adaptation of the task "Matching 10 graphs to 10 stories" from the time-distance activity. Indeed, the teacher aims at interpreting the graphs from a physical point of view.

Eighth lesson (physics)

The objectives of this lesson are making the word "magnitude" emerge and distinguishing it from units, discovering the device for measuring volumes, distinguishing volume and mass.

The teacher displays some questions and tasks to introduce and lead the lesson (see "t-T-lesson8-slides"). The proposed activities concern magnitudes, measuring device and measurement (see slides 9-10).

The teacher chooses some of the students' responses, takes pictures with a micro-document camera and displays them one by one in the classroom.

In particular, they discuss the students' responses displayed in the classroom in terms of:

- the name of the measuring device;

- the names given to the columns;
- the definition of volume and of mass.

At the end of the lesson, the teacher gives some homework to students, namely the "t-T-lesson8-exercise" about the mathematical and physical interpretation of a given graph.

Ninth lesson (physics)

The objectives are reading and interpreting a graph that represents a change of state. Both the physics and the mathematics teachers are present participate in the moments of classroom discussion and of analysis of the students' answers.

The exercise "t-T-lesson8-exercise" is revised through a multiple choice test, where the answers for each question are proposed by the teacher (see "t-T-lesson9-quiz" and the related EN version). In classroom, she pauses the quiz for coming back on a group of questions. First she asks to some students to give and explain their answer, then she displays and comments the graph of the results, provided by the software *Je lève la main*. All the results are stored by the software for the teacher's further analyse, in preparation of Session 10 that aims at working again on the target competences for remedying students' misunderstandings and difficulties.

Tenth lesson (physics)

The objective is remedying students' misunderstandings and difficulties linked to the mathematical and physical representation of a graph.

The teacher begins the lesson with a quiz on the main physical concepts of this sequence: magnitudes, units and measuring device (see the proposed questions in "t-T-lesson10-quiz").

The teacher displays the students' results to the question 1-4 and provides a first time of correction. Then she simply collects all the answer through the student response system for further analysis.

In the second part of the lesson, students have to work on remediation and complementary exercises about magnitudes, values and units of measure (see "t-T-lesson10-remediation"). The activity is composed of 3 parts:

1. Magnitude, unit, measuring device (vocabulary).
2. Characteristic magnitudes of water: characteristic temperatures of water.
3. Characteristic magnitudes of water: characteristic mass of water.

In each part, some exercises are proposed with increasing difficulty.

2.3 Technology

The student response system gives information for each student about his/her answer but gives also information for the whole class. The interpretation of these answers is not always easy for the teacher in the perspective of modifying his/her teaching: is the wrong answers due to a bad use of the clicker, or a lack of time or a misconception? The teacher is able to control students' use of clickers during the lesson because when a student answers her/her number appears in yellow on the screen shared within the classroom. Anyway, interpreting what the students exactly does is difficult.

We can identify a common scheme of action in the formative assessment practices of both the mathematics and the physics teachers:

- proposing a multiple choice test the classroom;
- showing or/and commenting results with students;
- analysing results on the spot or/and later, outside of the lesson time, for designing remediation.

Technology plays an important role in each of these phases. Questions are displayed in the classroom and students have to type their answer on their personal clicker and send it through the student response system. The system allows teachers to collect data from all the students in a short time and to have them organised in graphs (immediately exploitable in the classroom) and in tables (for further analysis), that serve as a support for teachers' analysis of the students' difficulties. This analysis influences a possible remediation phase that can be designed and implemented with or without technology.

In addition, the projector is used for simply displaying the task while the teacher and the students are discussing, and sometimes as a support for stressing something on the graph.

Also the functionalities of the micro-document camera are exploited in the classroom. In particular, the teacher takes picture of some of the students' work and displayed them in the classroom in order to share and discuss them with all the students.

2.4 Aspects of Formative Assessment

Both teachers consider the interpretation of a time-distance graph or a time-temperature graph as a challenge because they expect difficulties from students, in particular concerning the interpretation of the y-axis and the "behaviour" of the associated magnitude.

All along the sequence both teachers match the digital tools and their communication functionalities to the needs and abilities of the class and lead students progressively to a shared understanding of the graph concept from the mathematical and the physical points of views. The different phases where teachers appear as a resource for students (interpretation of the graph, experiment, drawing the graph from data, etc.) alternate with phases where students appear as a resource for their peers (debate in the classroom, work in group,...). When teachers display the task for supporting and encouraging classroom discussion or when they display the graph of the students' results, they engineer effective discussions, activating the students as instructional resources for one other. Moreover, teachers can use this strategy in the middle of a quiz to correct a group of answers and support students in answering the next group of questions. This allows them to clarify and share in the classroom the criteria for success and the learning objectives underpinning each question.

Teachers, working together, often jointly in the classroom, offer students an environment that allows a development of autonomy in front of the knowledge at stake. In this particular case of interdisciplinary work, we observed the phenomenon of a joint formative assessment strategy of maths and science teachers for giving feedback to students: they analyse jointly the graph of students' results. Such feedback goes in the direction of the individual students as the owners of their own learning as they were sharing results in the classroom.

3. Further Information

The good results to the final assessment that the physics teacher noticed constitutes an evidence of the effect of FA in this lesson: "*Looking at the last year results, when I didn't speak of 'story of a graph', there is a clear evolution*".

In terms of interdisciplinary work, each teacher attends almost all of the other's lessons. They intervene on the vocabulary and preparing or recalling the learning objectives of one other. Physics teacher wrote in her diary: "*Thanks to the cross observations, students make the link between the work done in physics and in mathematics*".

4. References

"Je lève la main" for clickers:

http://www.speechi.net/fr/index.php/home/evaluer/boitier-de-vote-interactif/

https://www.jelevelamain.fr/en/

For reading the whole case study in mathematics and science, see:

https://ife.ens-lyon.fr/fasmed/spip.php?article99