DEVELOPMENT OF FUNCTIONAL THINKING IN A STEM CONTEXT - ELEMENTARY SCHOOLS

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THE PROBLEM

- In this project, we are interested in the impact if the integration of STEM knowledge in primary schools, in Quebec Province, in Canada.
- The originality of this project lies in some different events that marked the history of mathematics and science as well, more specifically, the emergence of the concept of function.
- Actually, at the origin of the introduction of the concept of function in mathematics, underlies experimental motivation. Indeed, according to Kalchman (1999),

The concept of function originated when Galileo (1564-1642) proposed a program for the study of pendulum motion. By identifying variables in a situation, he sought to investigate and understand how they relate in a quantitative way. Following Galileo, most mathematicians believed that a function had the same quantitative relation throughout, and represented that relation using a single analytic expression. As a result, an informal ***definition of a function evolved as an analytic expression representing the relation between two variables***.

THE PROBLEM

However, a gradual expansion in the variety and use of functions forced mathematicians to begin accepting a broader concept of function (Kline, 1972). Led by Euler (1707 - 1783) and Lagrange (1736 - 1813), by the latter half of the 19th century, it was accepted that it was possible to have functions with different analytic expressions over different intervals. This change in the definition of function led to further investigation into the behaviour of functions, and it was eventually assumed that perhaps an analytic expression was not even required.

DESIGN OF THE PROJECT

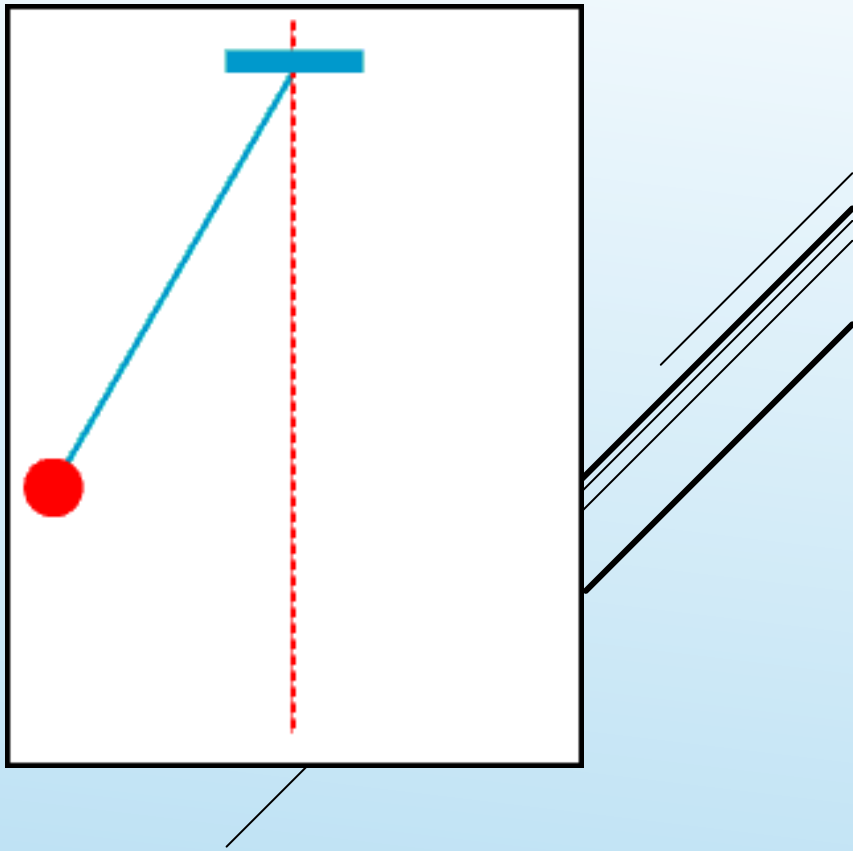
Based on historical emergence of the concept of function, we designed this project for grade 4 pupils, because at this level, the pupils have not yet seen the concept of variable.

Objectives:

- To explore how pupils deal with new abstract concepts such as variables.
- To check how using lab material can help them to learn mathematics.
- To examine how using technological tools (simulation) can help them to understand STEM concepts and to transfer them.
- To look out which discipline benefits more from STEM integration.
- To investigate the motivation toward the learning of STEM knowledge.

PROJECT IMPLEMENTATION

- To design this project, a team of 2 university professors, 4 research assistants and 3 elementary teachers worked together.
- **Implementation steps (S): 8 steps**
- **S1**: Pre questionnaire (questions about previous knowledge about pendulums, variables, charts and graphs, motivation to do STEM activities).
- **S2**: Introduction of the activity and explanation of pendulums and how they work (select variables to experiment: mass, length, initial angle (amplitude), and period). (Brainstorming and discussion: teachers will guide pupils to realized that, physically, we can not control the period (dependent variable)).

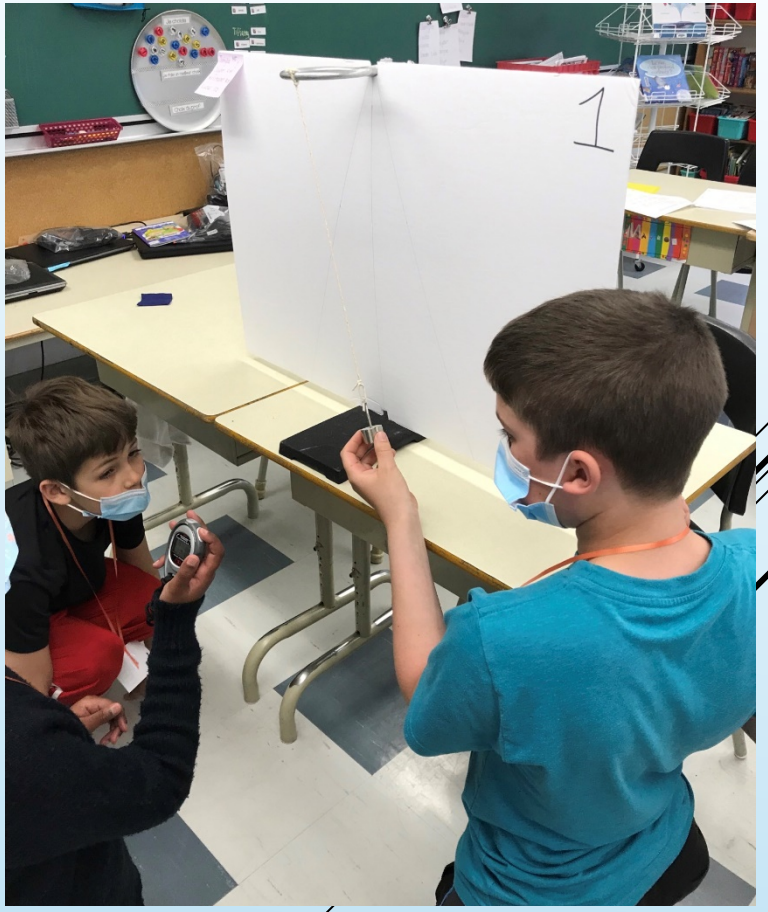


PROJECT IMPLEMENTATION

- **S3**: Making pendulum 1 and testing the effect of mass changing (keeping other variables constant)
  - **First measurements**
    - Keep same string or wire (length) and same initial angle (starting point)
    - **Collect data**

Mass (g)	20	50	100	150
10 periods (s)				
1 period T (s)				

- To fill the chart, we asked pupils to do 3 tests for each value of mass, then calculate the average.



PROJECT IMPLEMENTATION

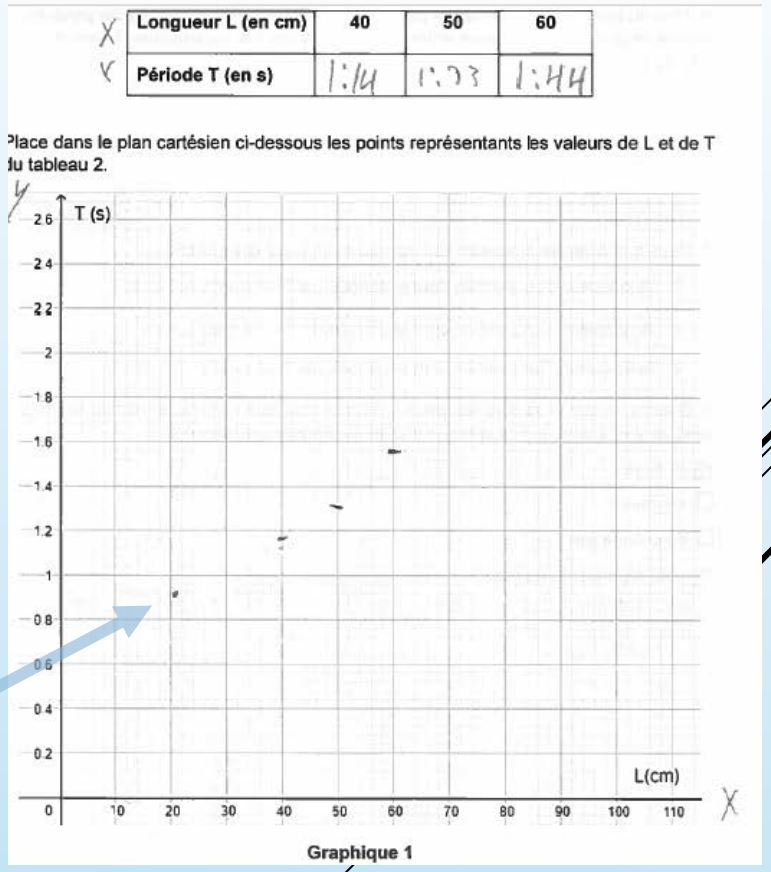
- **S4:** Making pendulum 2, by using three strings of different lengths (keep the same mass and the initial angle)

- Data

Length (cm)	40	50	60
10 Periods (s)			
1 Priod T (s)			

PROJECT IMPLEMENTATION

- **Some Excerpts from S4**
- **Excerpt 1**
- After plotting the graph (dots), we asked them if they can predict the period of a pendulum which has L=20 cm.
- The answer is shown in the graph (the Forth dot).



Longueur L (en cm)	40	50	60
Période T (en s)	1:14	1:33	1:44

Place dans le plan cartésien ci-dessous les points représentants les valeurs de L et de T du tableau 2.

Graphique 1

PROJECT IMPLEMENTATION

- **Some excerpts from S4**
- Excerpt 2: the Graph
- Excerpt 3: Extrapolation questions

5. À l'aide du graphique obtenu, peux-tu trouver les périodes qui manquent dans les cas suivants :

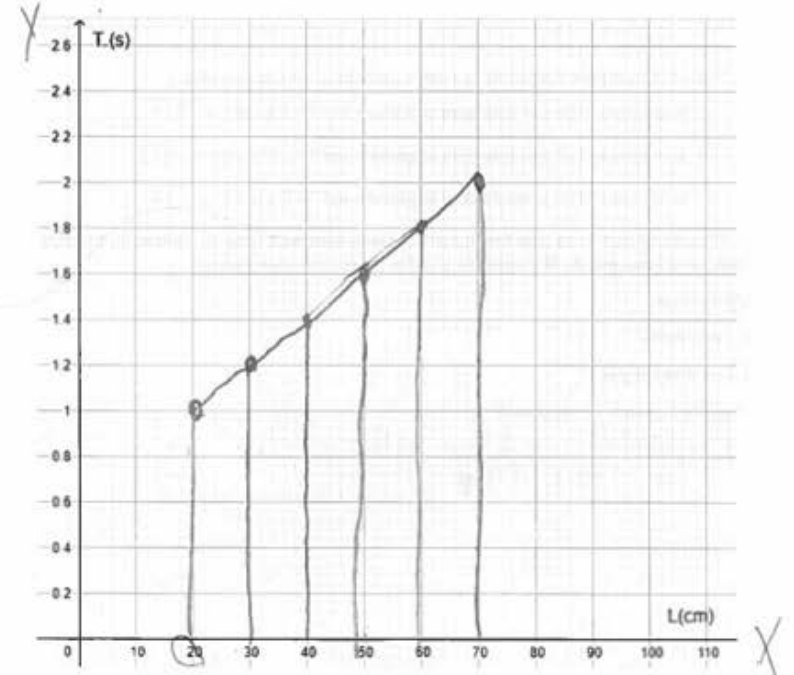
- la période d'un pendule de longueur 20 cm est T = ...0,8...
- la période d'un pendule de longueur 30 cm est T = ...1,2...
- la période d'un pendule de longueur 75 cm est T= ...0,2...

Tableau 2 : période en fonction de la longueur

(donne les mêmes valeurs à tout le monde : les valeurs augmentent)

Longueur L (en cm)	40	50	60
Période T (en s)	1,14	1,33	1,44

Place dans le plan cartésien ci-dessous les points représentants les valeurs de L et de T du tableau 2.



Graphique 1

PROJECT IMPLEMENTATION

- **S5**: The step 5 was designed to test how the initial angle (amplitude) affects the period of oscillation
- In this step, the length of the wire and the mass still constant during the experiment, BUT we change the initial angle of the pendulum.
- Chart:

Initial angle or amplitude (degrees)	5	20	40	60	80	100	120	140	160
10 Periods (s)									
1 Period (S)									

However, the associate teachers found this experience to be very demanding for the 4th grade pupils ➔ We canceled it for primary schools BUT we are keeping it for 8th grade pupils for the resumption of the project (in progress).

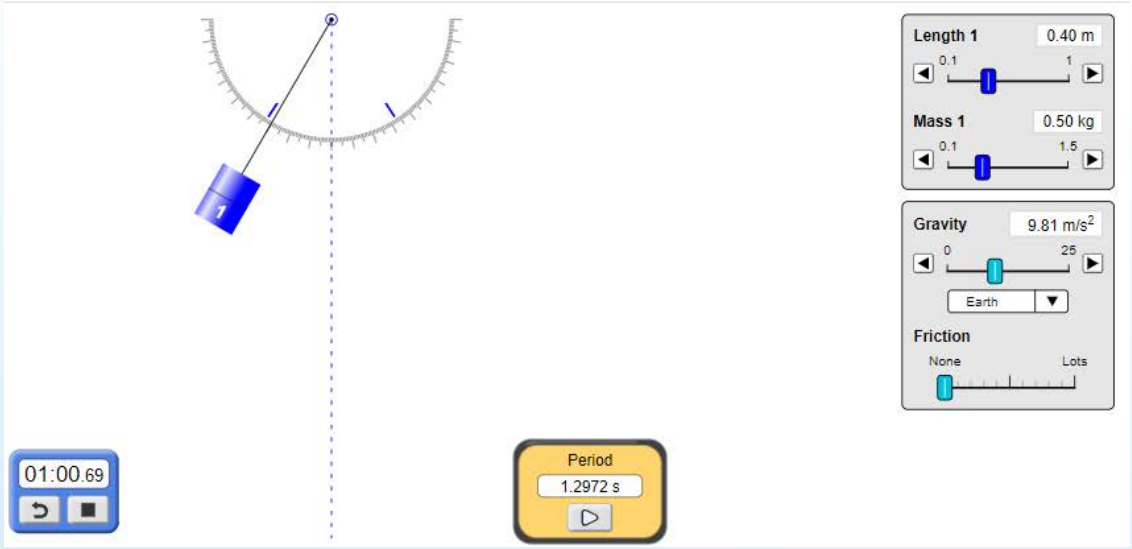
PROJECT IMPLEMENTATION

- **S6: work on a document providing some questions about data exploitation and the limits of the lab experiments.**
- **(Analysis in progress).**

PROJECT IMPLEMENTATION

- **S7: Simulation**
- In this step, we used PhET platform: https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html
- This step was to a certain extent easy as the pupils know already the pendulum and its variables, so we let them explore the platform at the beginning, then we asked them to use the simulation not only to produce the same data as in the laboratory experiments, but also to push back the limits encountered during these experiments.

PROJECT IMPLEMENTATION



- **S7: Simuation**
- Here is an example of the chart they asked to fill

L (cm)	20	30	40	50	60	70
Period (s)						

PROJECT IMPLEMENTATION

- **Excerpts of data collected by simulation.**

L (cm)	20	30	40	50	60	70
Period (s)	0,927	1,130	1,297	1,456	1,598	1,718

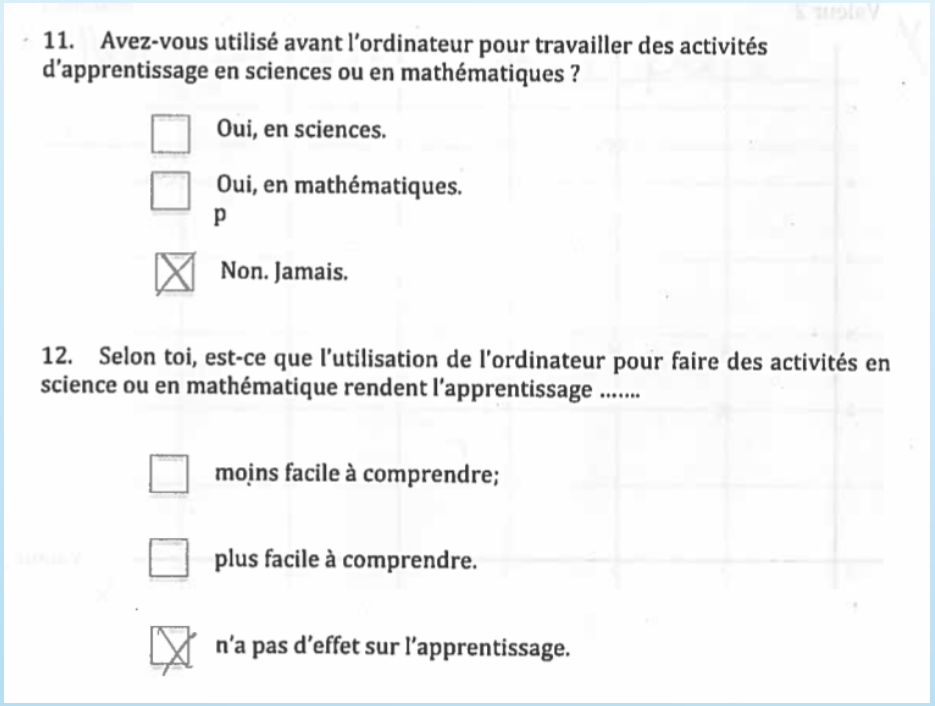
X	Longueur L (en cm)	40	50	60
Y	Période T (en s)	1:14	1:23	1:44

PROJECT IMPLEMENTATION

- **S8: Post questionnaire: same questionnaire as pre questionnaire** (questions about previous knowledge about pendulums, variables, charts and graphs, motivation to do STEM activities).

PRE AND POST QUESTIONNAIRES

- The analysis is in progress
- Pre questionnaire



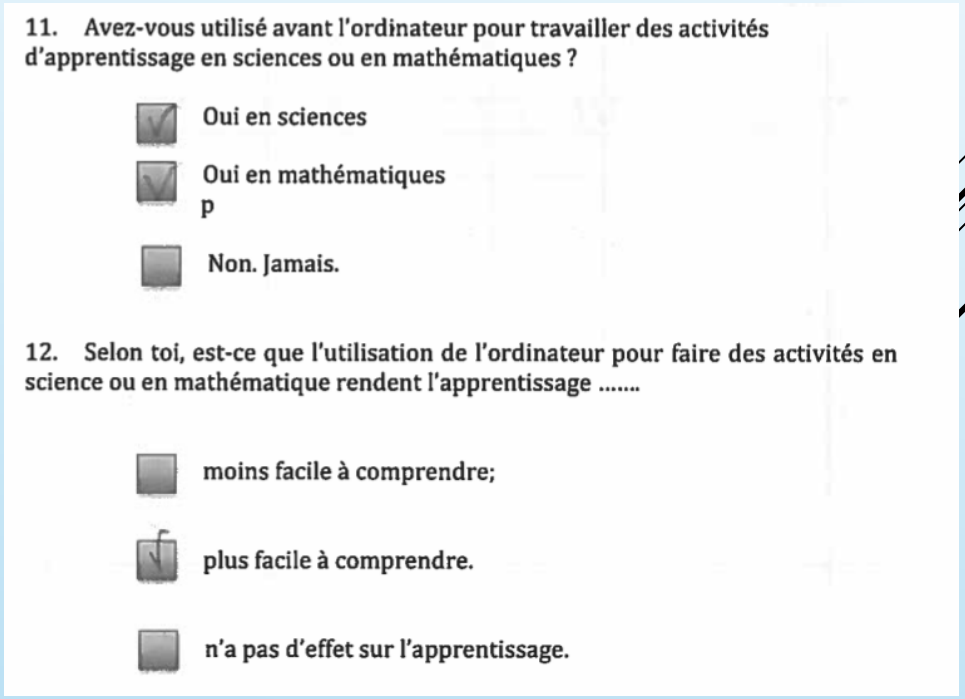
11. Avez-vous utilisé avant l'ordinateur pour travailler des activités d'apprentissage en sciences ou en mathématiques ?

- ☐ Oui, en sciences.
- ☐ Oui, en mathématiques.
  p
- ☒ Non. Jamais.

12. Selon toi, est-ce que l'utilisation de l'ordinateur pour faire des activités en science ou en mathématique rendent l'apprentissage .....

- ☐ moins facile à comprendre;
- ☐ plus facile à comprendre.
- ☒ n'a pas d'effet sur l'apprentissage.

Post questionnaire



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- ☑ plus facile à comprendre.
- ☐ n'a pas d'effet sur l'apprentissage.

CONCLUSION

Based on the preliminary scan, we expect to find that this project helped pupils to

- learn and understand variables and the relationship between variables (introduction of functions)
- consolidate some other mathematical concepts: average, charts and graphs
- learn how to use mathematical tools to predict (extrapolation)
- learn about the limits of tools used in labs.
- learn and understand deeply STEM concepts.

Moreover, the activities provided in this project seem to increase pupils' motivation toward learning STEM knowledge.

Wrap up:

- we look forward to hearing your feedback since the project is to be continued.
- We are open to collaborate with researchers in different countries.

- Questions?
- Feedback.

THANKS FOR YOUR ATTENTION