# THE INTEGRATION OF INNOVATIVE CAS SOFTWARE: THEORETICAL FRAMEWORKS AND ISSUES RELATED TO THE TEACHER

Jean-baptiste Lagrange
IUFM, University of Reims, France; jean-baptiste.lagrange@univ-reims.fr

*This paper introduces some results of ReMath related to Casyopée (a CAS learning environment incorporating a Dynamic Geometry window) regarding the theoretical frameworks involved and the teacher, and presents on-going research work about the dissemination of Casyopée beyond the ring of expert teachers. Preliminary findings indicate mid-adopters take approximately six months to appropriate the software, mid-adopters struggle as they attempt to integrate the tool's constraints, and expert teachers serve as mediators between mid-adopters and researchers.*

## INTRODUCTION

The rationales and history of the Casyopée project at an earlier stage have been explicated by Lagrange [1]. The Casyopée team brings together teachers and researchers to take up the challenge of using Computer Algebra Systems (CAS) to teach about functions at upper secondary level, consistent with recent curricula. The question addressed by the Casyopée team deals with the possibility of developing and disseminating a CAS environment that could help students to freely experiment, choosing their own way of solving and proving. Thanks to the ReMath European project, the Casyopée team was able to progress toward this goal. This paper introduces the Casyopée software, reports on the results related to Casyopée in the ReMath project, especially regarding the teacher, and presents ongoing research work about the dissemination of Casyopée. [For further information, please visit http://jb.lagrange.free.fr/site]

## CASYOPÉE IN THE REMATH PROJECT

The ReMath project addresses the task of integrating theoretical frames on mathematical learning with digital technologies at the European level. A specific set of six dynamic digital artefacts (DDA) has been developed, reflecting the diversity of representations provided by ICT tools. Seven teams from four countries are involved in this project. Casyopée is one of the six DDA, and its use has been investigated in Italy and France. In order to explain the software's functionalities, we now elaborate on the type of problem whose resolution can take advantage of Casyopée, and how. Figure 1 contains an example.

*Consider a triangle ABC. Find a rectangle MNPQ with M and Q on [AB], N on [AC], P on [BC] and with the maximum area*

**Figure 1.** A 'generic' optimization problem.

Constructing a generic triangle ABC in the geometrical window can be done after creating parameters in the symbolic (CAS) window. For instance, the points can be A(-a;0), B(0;b) and C(c;0), with a, b and c being three positive parameters. Then one can create a free point M on the segment [oA] (o being the origin) and the rectangle can be constructed using dynamic geometry capabilities.

In the Geometric Calculation tab (Figure 2), one can calculate the area of rectangle MNPQ and then define an independent variable. Numerical values of calculations and of the variable are displayed dynamically when the user moves free points. The user can then explore the co-dependency between these values. If this calculation depends properly on the variable it can be exported into the symbolic window; that is to say that, thanks to its CAS capabilities, Casyopée computes the domain and algebraic expression of the resulting function.

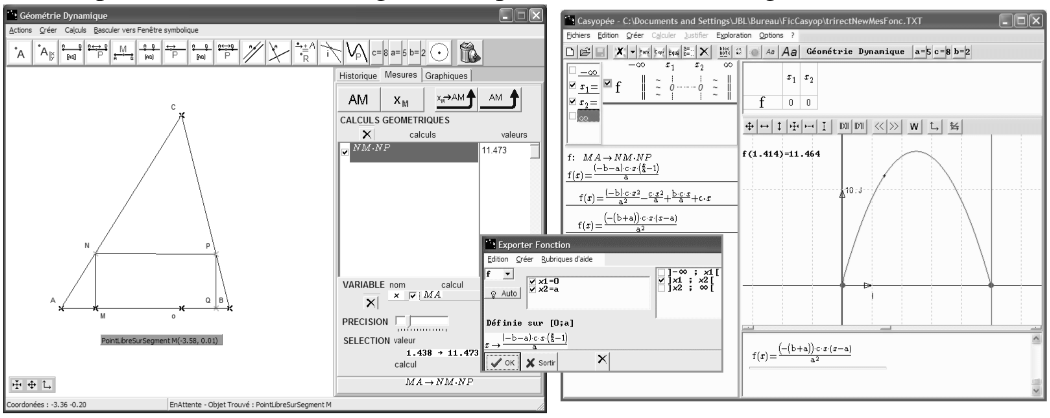


**Figure 2**. Casyopée's symbolic and DG windows and the exportation form.

After exporting into the symbolic window, one can work on various algebraic expressions of the function and on graphs. For instance, one can use properties of parabolas or algebraic transformations or Casyopée's CAS functionality of symbolic derivation to find the answer to the question. One can also use the graph of the function to conjecture about the maximum area.

## TAKING INTO ACCOUNT THE TEACHER IN CLASSROOM SCENARIOS

We report here on the Italian experiment [2], carried out at grade 12 over 11 school hours. This experiment highlights the role of the teacher for a successful implementation of Casyopée's potentialities under the inspiration of the Theory of Semiotic Mediation [3]. The designed educational goals were (a) to foster the evolution of students' personal meanings towards the mathematical meanings of function as co-variation, the notions of variable, and domain of a variable, and (b) to foster the evolution of students' personal meanings towards mathematical meanings related to the algebraic modelling of geometrical situations.

Students had previously received some formal instruction on the notions of variable, function and graph of a function, and on its graphical representation. The aim was to mediate and weave those meanings in the more global frame of modelling. Hence, the pedagogical plan was not constructed with the purpose of helping students become able to use Casyopée for accomplishing given tasks, but instead to foster the students' consciousness-raising of the mathematical meanings at stake. It was structured in cycles entailing: students' pair or small group activity with Casyopée for accomplishing a task, students' personal rethinking of the class activity (through the request to students of producing individual reports on that activity), and class discussion orchestrated by the teacher.

The familiarization session was designed as a set of tasks providing students with an overview of Casyopée features and guiding them to observe and reflect upon the "effects" of their interaction with the tool itself. Besides familiarization, the designed activities consisted of coping with "complex" optimization problems formulated in a geometrical setting and posed in generic terms, as in Figure 1. The aim was to elaborate on those problems so as to reveal and unravel the complexity and put into evidence step by step the specific mathematical meanings at stake.

The teacher's delicate role is to guide students to unravel such complexity and to make the targeted mathematical meanings emerge. The teacher has to achieve this objective by way of class discussions. The development of a class discussion cannot be completely foreseen a priori, it should be designed starting from the analysis of students' actual activity with Casyopée and of the reports they produce, and it would still depend on extemporary stimuli. Nevertheless in the design the Italian team tried to anticipate possible development of the pedagogical plan and to plan some kind of possible canvas for the teachers for managing class discussions. In contrast, the French team, influenced by other theoretical frameworks, like the theory of didactical situations [4] and the instrumental approach, designed its experiment through a careful choice of mathematical tasks, overlooking the definition of the teacher's actions. For the French team, it was very useful to learn from the Italian team how to pay more attention to design of the teacher's action.

## DISSEMINATING CASYOPÉE TO 'SECOND ADOPTERS'

We[1] are now studying the dissemination of Casyopée. A first assumption is that a CAS tool designed by researchers to have a high potential, like Casyopée, will not necessarily be easy and welcome for teachers not involved in the project, even if it has been developed in close connection with expert teachers. Research about dynamic geometry environments [5] shows that there is a wide gap between researchers' visions about the contribution of digital tools and ordinary teachers' expectations with regard to technology. Our aim is then to investigate ways of bridging this gap. Another central assumption is that researchers have to consider

[1] Nguyen Chi Thanh, from the Hanoi Pedagogical University, is working with the author in a postdoctoral contract supported by the AUF (Agence Universitaire pour la Francophonie).

the dissemination of their production as a research work in itself, creating communities involving teachers-users and researchers to produce varied resources associated with the use of the software.

In these communities all teachers are not to be considered at the same level. We propose considering “first-adaptors,” or “experts,” to be teachers that have been constantly associated with the project development and think of the integration of Casyopée as a natural process. We propose to consider also “mid-adopters,” teachers who are interested by using technology in the classroom, but were not associated with Casyopée’s development. We expect that these teachers will be primarily interested in easy-to-achieve and close-to-curriculum applications of Casyopée, and sensitive to conditions of its successful integration. We also expect that these teachers, more than the experts, will be concerned by problems and constraints such as those related to the time required to implement technologies in their classes, to curriculum requirements, to overall school organisation issues, and to training needs. All other teachers at upper secondary level, as potential users of Casyopée, form a third layer.

It seems to us that the transition from experts to mid-adopters is crucial. If we can “break the barrier” around experts, we will have made a very significant step towards dissemination, especially by learning about the needs of these “second adopters’” and their paths toward integration. Our idea is to use “scenarios” (classroom activity plans) as a means for communicating between layers: the elaboration and experimentation of scenarios by second adopters will be first a way of communicating between experts and mid-adopters: mid-adopters will propose uses corresponding to their needs and ask the experts for their advice and support. The scenarios will be designed to be accessible to all teachers and to be a way to communicate between the second and third layers.

At a theoretical level we first consider these “scenarios” as “boundary objects” between researchers and teachers and between teachers in different layers. Their importance has been noted by researchers concerned with interaction between communities [6]. Boundary objects do not carry meaning with them, instead meaning is recreated, in action. We cannot assume that the meanings that we build into any artefact are transparent to teachers. Teachers construct their own meanings, influenced by their past experiences and beliefs as well as their interactions with these objects. Mutual negotiation and meaning-construction thus should be established as the norm for both sides of the boundary, rather than the preserve of one protagonist.

The second theoretical notion is instrumental genesis [7]. The potential role of digital tools cannot be expected to be transparent and if they are to be integrated in a significant form into mathematics classrooms, an understanding of how to engender the process of instrumental genesis is crucial. In the case of working with teachers, the instrumental genesis process is particularly complex since artefacts become instruments not only in the mathematical practices of teachers but also in their didactical practices.

## METHODOLOGY

### *Expert teachers*

Two teachers (named here Bernard and Xavier) were especially involved in the cyclical process of specifying functionalities for a CAS software, contributing to the software development, and experimenting with their classes. Crucial steps in the project, especially the decision to develop a software environment around a symbolic kernel and to append a Dynamic Geometry window, were undertaken as a consequence of dissatisfactions they expressed after classroom experimentations. The design was driven by their careful attention to the consistency of the computer representations of the mathematical objects and to the design of Casyopée as a tool helping students rather than constraining them.

Bernard and Xavier and their students feel comfortable with Casyopée in spite of its constant evolution. Casyopée's complexity is generally not resented by their students because of the careful introduction these teachers provide, making the connections between Casyopée's objects and the mathematical objects.

### *Mid-adopters*

In the same region of Rennes where Bernard and Xavier teach, a group of six teachers had been constituted in the IREM (Institute for Research in Mathematics Teaching) to experiment with the Interactive White Board (IWB). During three years they had experimented with the use of software packages (DG and CAS) on the IWB, and they were keen to enter a new project. For us they were good candidates to be "mid-adopters": they were convinced that technology can support mathematical teaching and learning, they were relatively experienced in the classroom use of technology but were not, like Bernard and Xavier, involved in Casyopée's history. In the present project their role is to prepare and experiment under the supervision of Bernard and Xavier scenarios that will be disseminated to mathematics teachers together with Casyopée on the professional digital workspace for teachers in Brittany.

## PRELIMINARY FINDINGS

At the present stage of this research study, we can only outline some features that we found relevant or surprising. As we are analysing the data (records of meeting sessions and scenarios proposed and experimented by second adopters), the author will be able to present a more complete set of findings at the CAME meeting.

Six months were necessary for mid-adopters to appropriate the software in order to be comfortable in the classroom. In contrast to the experts, accustomed to explaining to students that some difficulties or malfunctioning may occur, the mid-adopters were very worried about presenting to their classes software that is "not totally finished." It took also time for these teachers to understand how the characteristics of the symbolic kernel influences Casyopée's operation.

Because of their experience with other software, the mid-adopters found often difficult to integrate Casyopée's constraints. For instance, seemingly drawing on their work with numerical dynamic geometry systems, they created indistinctly as free points the "generic points" defining the figure (the triangle's vertices in figure 1) and the "moving point" defining the variable elements of the figure (a vertex of the rectangle in figure 1). The consequence is that the "exportation process" did not work, because too many free points were involved in the variable elements.

It is a surprise that the mid-adopters never considered scenarios about modelling a geometrical dependency like in the ReMath project. Our hypothesis is that they already have strategies to handle these problems in the classroom, based on numerical dynamic geometry systems. In contrast with the experts, they do not see the limitations of these strategies and Casyopée's advantages. The scenarios they created show how they were attracted by other functionalities of Casyopée that we did not expect to be first considered.

Another feature is the respective roles of the researchers and of the expert teachers. Researchers very often need to answer second adopters' questions regarding the software and the aims of the development and thus need to be very active in the meetings. The expert teachers generally act as mediators, explaining specific positions. Their contribution is essential for researchers to understand mid-adopters' reactions.

## CONCLUSION

The acceptability of CAS by teachers is central in Casyopée's design. The ReMath project experiment shows that, beyond software design, a crucial issue is to take into account the teacher's activity in classroom scenarios. Preliminary findings of the dissemination ongoing project indicate several ways in which mid adopters' view of Casyopée contrasts with experts'. Further work will help to understand the differences between layers of teachers and how this understanding can be a basis for building communities of teachers and researchers to support dissemination.

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