QUALITY PROCESS FOR DYNAMIC GEOMETRY RESOURCES: THE INTERGEO PROJECT

Jana Trgalova*, Ana Paula Jahn**, Sophie Soury-Lavergne*
* EducTice, INRP; LIG, Grenoble, France
** UNIBAN, São Paulo, Brazil

In this contribution, we present the European project Intergeo whose aims are first to develop a common language for a description of geometric figures that will ensure interoperability of the main existing dynamic geometry systems, and second, to gather and to make available pedagogical resources of a good quality. This text focuses on the quality process for dynamic geometry resources aiming at their perpetual improvement.

Keywords*: pedagogical resource, quality of a resource, dynamic geometry, teacher training*

INTRODUCTION

This contribution concerns the issue of integration of ICT tools into teachers' practices and the means of supporting it. One of the keys is to provide teachers with pedagogical resources helping them to develop new activities for their pupils. However, we now know that the availability of resources is not sufficient. On the one hand, the abundance of resources makes difficult to find appropriate and quality resources (Guin and Trouche 2008, Mahé and Noël 2006). On the other hand, the availability of resources does not solve the problem of their appropriation by the teachers, which requires an evolution of teachers' competencies and their conceptions about the role of technology in teaching and learning mathematics (Chaachoua 2004).

This leads to consider the issue of teachers training. Numerous research works pointed out the efficiency of training based on co-design of pedagogical resources (Krainer 2003, Miyakawa and Winsløw 2007). Various training actions have been developed in France based on this principle, e.g., SFODEM and Pairform@nce (Gueudet et al. 2008). In Brazil, AProvaME project aimed to study the effects of a collaborative design of resources involving ICT tools by the teachers on their conceptions about the notion of proof and its teaching, as well as about the role of technology in mathematics learning (Jahn et al. 2007).

THE INTERGEO PROJECT

Despite the availability and accessibility of ICT tools, and despite the recommendations in the curricula to use technology in France and in Brazil, teachers are reluctant to use these technologies (Artigue 2002). In the case of dynamic geometry systems (DGS) several reasons explain this resistance. The most important is certainly the shift in considering mathematical activity and teacher profession caused by the introduction of ICT into mathematics classroom (Lagrange and Hoyles 2006). However, other obstacles to using DGS by the teachers can not be neglected. First, the complexity of choice of a reliable and easy to use DGS among a number of existing systems, and the resulting constraints on the choice of resources that must match the chosen DGS. Next, it is hard to find pedagogical resources appropriate to a specific educational context. This can be attributed to a great amount of resources available on the Internet, but mostly to the lack of metadata, providing an accurate description of the resource content. Moreover, available resources do not often have the required quality to be used in a classroom. The difficulty for a teacher to evaluate quality and adequacy of a resource to her/his specific context is an obstacle to the ICT integration. For this reason, tools for indexing resources, as well as evaluating their quality appear essential.

These considerations lead to 3 goals of Intergeo project (www.inter2geo.eu/fr): (1) interoperability of the main existing DGS, (2) sharing pedagogical resources, and (3) quality assessment process of resources discussed in this paper.

THEORETICAL BACKGROUND

Notion of pedagogical resource

First, it is important to clarify what we mean by pedagogical resource. Indeed, Noël (2007) points out that the issue of resource evaluation relies on the definition of what is a pedagogical resource. Nevertheless, according to the author, in spite of numerous efforts, the definition of pedagogical resource remains vague and rather broad in its scope. The most often used one is drawn from LOM standards (2002): "… *any entity, digital or non-digital, that may be used for learning, education or training*" (p.5). Flamand (2004) specifies that in order to enhance learning, a Learning Object has to possess intrinsically a pedagogical intention. Thus, for the purposes of Intergeo project, we will consider as resources those "entities" (dynamic geometry figures, texts…) for which pedagogical intention is specified.

In addition, we share Trouche and Guin's (2006) point of view, which, referring to the instrumental approach (Rabardel 1995), considers a pedagogical resource as an artefact that needs to be transformed into an instrument by a teacher in the process of its use in her/his class. For the authors, usage of a resource is a condition for its existence. Resources are therefore living entities in evolution through their usages. In this perspective, the quality assessment process of Intergeo DG resources aims at enabling their perpetual improvement.

Quality assessment process

The quality of a resource depends on its intrinsic characteristics, as well as on its adequacy to the context in which it will be used. A given resource can be "good" in one context and "poor" in another. Thus clarifying its educational goals and the school context in which its use is intended is also essential in determining and improving the quality of the resource.

Mahé and Noël (2006) constituted an evaluation typology based on a detailed analysis of evaluation means set up by various web sites offering pedagogical resources: a priori evaluation by the adherence institution; validation of resource conformity to a deposited content; peer-review by expert teachers; user evaluation;

cross-evaluation both by peers and users. The quality assessment in Intergeo project regarding DG resources consists of an evaluation by users and a peer review of a number of resources by a group of teachers supervised by math education researchers based on a priori analysis, use in a class, and a posteriori analysis of the resources. This process corresponds to the 5th type of evaluation mentioned above, rarely encountered according to the authors.

Mahé and Noël (ibid.) bring to light critical aspects of a resource to take into account in the evaluation process: technical aspect, content, design aspect and metadata. Criteria we have set up for the quality assessment process of DG resources draw from these categories, as well as from theoretical frameworks suitable for resource analysis: (1) *didactic theories*, namely Brousseau' theory of didactic situations offering tools for analysing pupil's activity and teacher's role, and Chevallard's anthropological theory allowing to address issues of resource adequacy to institutional expectations, and (2) *instrumental approach* (Rabardel 1995) providing a framework for instrumented activity analysis.

USER EVALUATION OF THE QUALITY OF A RESOURCE

Our elaboration of a questionnaire for DG resource quality evaluation by users started by listing characteristics or elements of a resource related to its mathematical, didactical and pedagogical quality. We attempted to obtain a list as complete as possible. These characteristics were classified into 9 classes considered as relevant indicators of the resource quality: metadata, technical aspect, mathematical dimension of the content, instrumental dimension of the content, potentialities of DG, didactical implementation, pedagogical implementation, integration of the resource into a teaching sequence, usage reports. In what follows, we give an overview of criteria related to four classes referring to mathematical and didactical value of a resource.

Mathematical dimension of the content of a resource

There is no doubt that, for a resource to be usable in a school context, its content has to be mathematically correct. Adequacy of the content with the curricula allows the evaluation of the resource utility. Finally, mathematical activities need to be in adequacy with the declared educational goals.

Criterion	*Question*
Validity	Are the activities in the resource correct from a mathematical point of view?
Adequacy to the curriculum	Are the activities in adequacy with curricular and institutional constraints?
Adequacy to declared goals	Are the activities in adequacy with the declared educational goals?

Table 1. Mathematical dimension of the content of a DG resource

Instrumental dimension of the content of a resource

When a resource includes a DG file, it is necessary to check the coherence between the proposed activity and the geometric figure. In addition, the figure should behave as expected. Particular attention should be paid to the handling of limit cases and of numerical values such as measures of lengths and angles. Indeed, the dynamic diagram should behave according to mathematical theories and didactical goals. If special functionalities, such as macro-constructions, are used, a description of their operating mode will make easier the appropriation of the resource by a teacher.

Criterion	*Question*
Adequacy of diagrams	Do the dynamic diagrams correspond to the proposed activities?
Behaviour of diagrams	Do the dynamic diagrams behave as expected in the activity?
Management of limit cases	Is the management of limit cases in the dynamic diagrams acceptable from the mathematical point of view?
Management of numerical values	Is the management of numerical values acceptable in the sense that it does not hinder mathematical aims of the activity?
Special functionalities	If the diagrams rely on special functionalities (e.g., macro-construction), is their operating mode clearly described?

Table 2. Instrumental dimension of the content of a DG resource

Potentialities of dynamic geometry

Numerous researches on DG put forward its potentialities and their contribution to the learning of geometry (Laborde 2002, Lins 2003, Tapan 2006). Criteria in this class aim first at evaluating how these potentialities are exploited in the resource, and more specifically to what extent DG contributes to improve learning activities comparing to paper and pencil environment. Second, its contribution to the achievement of educational goals is also analysed. This class comprises two criteria: (1) specific features of DG offering an added value to the resource, (2) role and use of drag mode, drawing on diversity of DG potentialities highlighted by research works (Laborde 2002, Healy 2000, Mariotti 2000). Even if a resource cannot benefit from each of them, we consider a resource that does not take any advantage of DG is of poor quality. Our hypothesis is that teachers perceive DG mainly as enabling to drag points to make pupils observing invariant properties (Tapan 2006).

Criterion	*Question*
Elements contributing to the added value of DG in the resource	Is DG a visual amplifier improving graphical quality and accuracy of diagrams?
	Is DG used to obtain easily and quickly many cases of a same figure?
	Does DG provide an experimental field for the learner's activity?
	Do the feedbacks enable students validate their constructions by themselves?
	DG offers a possibility to articulate different representations of a same mathematical problem. Is this possibility used in the resource?
	Does DG allow students to overcome the spatio-graphical characteristics of a diagram to focus on its geometrical properties?
	Is the activity specific to DG, i.e., it would be meaningless without it?
	Does the use of DG in the activity contribute to achieve the educational goals?
Use and role of the drag mode in the resource	Is dragging used to illustrate a geometrical property, i.e., students are encouraged to drag elements and observe a given property that is invariant while dragging?
	Is dragging used to conjecture geometrical relationships, i.e. the point is to observe whether a supposed property is invariant while dragging elements?
	Is dragging used to study different cases of the diagram?
	Is dragging used to obtain a specific configuration satisfying given conditions?

	Is dragging used to identify dependencies between objects?
	Is dragging used to illustrate link between hypotheses and conclusion in a theorem, i.e., the point is to momentarily satisfy hypotheses by dragging elements (soft construction) and consider obtained properties as necessary consequences?
	Is dragging used to explore trajectories of geometrical elements (locus, trace)?
	Is the use of dragging explicitly mentioned in the instructions for students?

Table 3. Potentialities of dynamic geometry

Didactical implementation of the resource

Trouche (2005) points out that a successful integration of ICT requires a specific organization of pupil-computer interactions, which he calls "class orchestration". The author emphasises the importance of instrumental processes management in relation with learning mathematics. For this reason, we are convinced that a quality resource should provide a kind of assistance related to the class orchestration by means of elements concerning mathematics learning management with technology, which would help the teacher organize favourable learning conditions. We propose the criteria and questions, reported in table 4, addressing the issue of didactical implementation of a resource.

Criterion	*Question*
Mathematical learning management	Do the students get involved easily in the proposed activity?
	Does the activity let enough initiative to students to choose their strategies?
	Does the resource describe students' possible strategies and answers?
	Does the resource provide information about teacher reactions to students' errors?
	Does the resource provide information about the teacher interventions at the beginning of the activity with the students?
	Does the resource provide information about the teacher interventions making the students' strategies evolve?
	Does the resource provide information about the teacher interventions during the phase of synthesis?
	Does the resource provide information about the validation phases?
	Does the resource discuss main characteristics of the activity, their effects on students' behaviours and other possible choices?
Instrumented activities management	Does the resource provide information about feedback from the software?
	Do the dynamic diagrams provide feedback enabling the student to progress in solving the given tasks?
	Does the resource provide information about the possible teacher interventions regarding instrumental aspects of the activity?

Table 4. Didactical implementation of a resource

The resulting questionnaire comprises 9 classes with 59 questions altogether. It deals with a great variety of aspects of a quality DG resource and should be comprehensive. However, the questions are not homogenous from the point of view of expertise required to understand and to be able to provide a sound answer to each question. It can be expected that all users will not evaluate all aspects of a resource, but they will rather focus at those that correspond to their own expertise and their own representation of what is a quality resource. Nevertheless, the quality of a resource will take account of all evaluators; therefore we expect that each aspect will be evaluated by some of the users.

Given the length of the questionnaire, it seemed necessary to start by proposing a lighter version to users focusing on a few large questions (one per class) addressing globally each aspect of the resource. At the same time, the user will have the possibility to deepen her/his answer by answering more precise questions related to aspects s/he will wish to analyse further, according to her/his expertise. Moreover, s/he will be given opportunity to go back to the evaluation repeatedly. Note that the process of resource ranking (under development) will take account of the user's declared expertise and assign a weight to each provided answer accordingly.

Since the end-users of the questionnaire are teachers, we wished to test relevance and clarity of the questions. For this purpose, we organized a pilot experimentation with a group of teachers using a simplified version of the questionnaire. The experiment and some results are described in what follows.

EXPERIMENTATION

Some elements of the initial questionnaire available in (Mercat et al. 2008) have been tested in Brazil, within an in-service teacher training "Geometry" module. Our goal was to analyse the relevance of evaluation criteria we defined, as well as to understand what a quality resource is for the teachers. A few more open questions were added aiming at identifying elements of a resource the teachers consider as helpful in order to appropriate and use the resource in their classes. A DG resource has also been designed to control some of its aspects for the experiment purposes and to be relevant for a teacher training.

Presentation of the resource and of the questionnaire

The resource addresses the "quadrilaterals" topic and makes use of Cabri-geometry. It is constituted of a student worksheet, a teacher document and three DG files: two dynamic figures (cf. Fig. 1) and one macro-construction.

The teacher document provides a description of the resource: topic, school level, educational goals, prerequisites and required material. It also provides a brief presentation of the suggested organization of the sessions: classroom setting and roles of teacher and students.

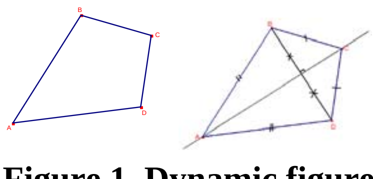

Figure 1. Dynamic figures composing the resource

The first mathematical activity, whose aim is to introduce a special type of a quadrilateral, an isosceles kite, draws from the idea of a "black box" specific to DG environments. It consists in reproducing a geometrical figure that behaves in the same way as a given model. Students are expected to explore the model in order to identify relationships between its elements, then to reconstruct the kite and validate their construction by using the macro-construction. In the resource, the exploration phase is partly guided to lead the students to characterize a kite by means of a maximum of its properties (related to its sides, angles and diagonals). Indeed, the activities are intended for 12-14 year old students and the instructors consider inappropriate to let them completely responsible of exploring the figure and identifying properties and relationships linking its elements. In the second activity, the students are invited to explore the figure and to conjecture a possibility to obtain other types of quadrilaterals (square, rhombus, non squared rectangle) from the kite. In both activities, the drag mode is essential to explore given dynamic diagrams.

For the purpose of the experiment, we selected and adapted several questions from the Intergeo questionnaire (cf. Fig. 2), namely those concerned with mathematical and instrumental quality of the resource, potentialities of DG and didactical implementation of the resource. The questions regarding DG are intentionally open aiming at highlighting which elements the teachers spontaneously mention as contributing to the added-value of DG in the resource.

Regarding the **pupil's worksheet**:

1. Are the texts of the activities:
   a. Clearly formulated?
   b. Mathematically correct?
2. Are mathematics tasks proposed to pupils easily identifiable?
3. Are DG figures provided with the resource:
   a. Easily accessible?
   b. In adequacy with the proposed activities?
   c. Do the figures behave as expected?
4. Would you use this kind of resource with your pupils? With or without modifications? Which ones?

Regarding the **dynamic geometry**:

1. What do you think about the role of dynamic geometry in the resource? Do you think this sequence could be proposed in paper-and-pencil environment?
2. If not, what aspects justify the use of the software?
3. Does the use of drag mode contribute to the achievement of the declared educational goals?

Regarding the **teacher document**:

1. What elements of the teacher documents do you consider as essential and the most relevant for a pedagogical use of the resource?
2. Do you think this document is sufficient for an easy appropriation of the proposed teaching sequence? Do you miss some information? Which?
3. Would you like to have other types of material or documents? Which ones?
4. Suppose that some of your colleagues have tested the resource in their class. What information do you consider important to be shared their experience?

Figure 2. Questionnaire for resource evaluation used in the experiment

Written answers provided by the teachers were one kind of data we gathered. These were completed by field notes of an observer recording relevant elements of exchanges among teachers.

Experimentation and first results

The experimentation consisted in one 2h30 training session for 22 secondary mathematics teachers, who had, in average, six years of experience in teaching and most were "beginners" in DG. The training session was organized in three phases: solving activities from the student worksheet, a priori analysis of these activities, and analysis of the resource guided by the questionnaire (cf. Fig. 2). In what follows, we describe the phase 3 and present the first results.

In the teacher document, the participants particularly appreciated the brief description of the sequence considered as a kind of the resource "*visit card*", as well as the synthetic description of the sequence organisation: "*very well like that, one gets directly every essential information*"; "*one understands immediately how to organise the sequence*".

As regards the student worksheet, the teachers have found the tasks easily identifiable, mathematically correct and clearly formulated. A special attention was paid to the vocabulary with the intention to make the wording of activities accessible to pupils. The teachers used these worksheets also to understand the sequence organisation and its progression: "*student sheets allow us to understand well the whole sequence and to spot contents and objectives*"; "*Student sheets are very well designed. […], one sees clearly the sequence progression: observation of sides, symmetry between vertices and angles. Then, the construction is proposed and finally the study of some cases […]*".

Regarding elements helpful for resource appropriation but missing in the resource, the teachers expressed a need to understand how the macro had been constructed and how it works. They would also have liked to have more information about the teacher's role: what interventions and when, particularly during the institutionalisation phases; how to assist students' work. Some teachers pointed out that a document with reports of use, containing expected solutions and answers, but also possible students' difficulties accompanied with advices how to cope with them (e.g., student worksheet with commentaries for a teacher) would be helpful for a better appropriation of the resource.

Regarding DG, all teachers find unquestionable its contribution in the resource: "*activities specific to Cabri*"; "*the software is essential*"; "*impossible without Cabri*". This is not surprising since the resource was designed for. The teachers state more precisely that "*the software favours checking of properties*"; "*without drag mode and possibility to modify diagrams, properties wouldn't be visualized"*. They spontaneously mention that dragging enables manipulating the figure and thus identifying its properties; checking properties; obtaining easily many different cases of a same figure; constructing figures easily, quickly and more precisely; making conjectures.

It is important to note that the teachers formulated all these criteria spontaneously, but they admitted that they would not have been able to do it without the framework of the questionnaire and without having done previously an a priori analysis of the resource. The questionnaire helped them focus on important aspects of the resource and they were able to provide a deeper analysis than expected. Thereof, the criteria set up for the evaluation questionnaire seem to be understandable by teachers, but what's more, they helped them analyse the quality of the resource. Thus, the questionnaire is not only a tool for characterizing the quality of a resource and for highlighting aspects to be improved, but it can also be used to train users' awareness of positive and negative aspects of a resource and in this way develop their professional skills enabling them to use it efficiently with their pupils.

CONCLUSION

The results from the experimentation show the importance of training teachers to resource analysis. Indeed, the questionnaire helped the teachers focus on important aspects of the resource to look. These aspects were rarely taken into account before the training session. Among those, there is the teacher document containing information about the implementation of the resource and the added value of DG, in particular the role of drag mode.

On the other hand, the quality assessment process will lead to an improvement of a quality of resources, both at the metadata level highlighting information allowing an easier spotting of relevant and quality resources and at the level of the resource itself. Indeed, the quality criteria may be considered as a grid allowing to improve certain aspects of resources or to design new resources satisfying these criteria from the very beginning. Thus, this process can eventually give rise to a model that would act as a guide for resource designers by pointing necessary elements and helping make them explicit in an understandable and accessible way for potential users.

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