Interoperable Interactive Geometry for Europe: an introduction

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1 Introduction

Interactive or dynamic geometry is one of the three major software pillars of technology-based mathematics education, next to computer algebra systems (CAS) and spreadsheets. We can trace back the roots of this great tool for visualization and interactive manipulation to the work of Sutherland (1963), a system called Sketchpad which laid ground in computer science and human computer interaction. Since the introduction of Cabri-Géomètre (Baulac, Bellemain and Laborde, 1988) and Geometers' Sketchpad (Jackiw 1991), we could see several generations of such tools applied in mathematics education. During the last 20 years, interactive geometry software could establish a settled position in the mathematics education community, and for many researchers it is no longer a question whether to use these tools or not, but how to use them.

However, what has convinced many in the academic field of mathematics education has still not become a standard in mathematics teaching in the classrooms (Intergeo Consortium 2008). While the lack of availability of

computers in some schools or the cost of licensing might be reasons for the apparent underrepresentation, this cannot be the only reason. In particular, in Europe, most schools can offer access to networked computers, and there are several interactive geometry packages available free of cost. Also, there are thousands of web pages containing sketches, examples, activities and exercises—subsumed as “resources”—using dynamic geometry.

An initiative of Christian Mercat back in 2006 started what became the Intergeo project (Kortenkamp et al. 2009), funded through the eContentplus program of the European Union between October 2007 and 2010. This project intended to bring together teachers at all school levels from K-12 to university teaching and the wealth of resources available on the internet. By assembling the consortium and associate partners of the project from several major interactive geometry software producers from Europe (among them Cabri, Cinderella, GeoGebra, GEONExT, Géoplan-Géospace, TracenPoche, WIRIS and Z.u.L/C.a.R.), it was possible to include not only more than 3,000 resources contributing to the project, but the project could also strive for a common exchange format, a *lingua franca* for interactive geometry. A necessary condition for a true re-use of a resource lies in the possibility of using the resource in the environment familiar to the user regardless of the particular system used to create the resource.

In addition, it was not clear how teachers can find exactly the content needed for his or her particular classroom situation. Helping people in this search for a specific content usually means adding to the resource itself meta-data providing information about the resource. Then search engines can identify material based on keyword searches. The task is not trivial for mathematics and in particular geometry, as information cannot be extracted from a formula or graphical representation as easily as from a text.

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Adding a European dimension makes the situation even worse: the names of theorems or notions in mathematics are not consistent throughout different languages, and even translating them does not help. A famous example is “Thales’ theorem,” which can be a theorem about right-angled triangles inscribed in circles or about rays that intersect parallel lines, depending on whether you are talking about *el teorema de tales*, *den Satz des Thales*, *le théorème de Thalès*, or *o Teorema de Tales*. Another illustration comes from statistics: A *camembert* would not be the correct word if you are translating *pie* to French for a recipe book! For mathematics it is.

The only solution to add enough information to resources to make them browsable and searchable for teachers from all over Europe is to base the metadata on an ontology, a formal representation of concepts from mathematics. In Intergeo, an ontology of concepts, topics and educational regions (Libbrecht et al. 2008) was created and used by the search engine in order to help the users find exactly what they need, even if it is only available in a language different from the query formulated by the user.

But Intergeo did not only address the technical hurdles of finding and using interactive geometry resources. If there are more than just a few resources but several dozens as a result for a query, then it is necessary to rank them according to quality criteria. It is a difficult task to create such quality criteria, as they depend on several factors. Also, even if there are such criteria, the evaluation of the resources is time-consuming and an additional burden to those who just want to use them. With the available funding, the project could give limited support to in-classroom evaluations, but for reliable data Intergeo depends on the feedback of its users. The development of a quality questionnaire for users within the project took this as a chance. It resulted in a flexible questionnaire that can be used both for in-depth analysis as well as quick evaluations. Moreover, the questionnaire and its development have been identified as a chance for continuous professional development of teachers.

Concluding, the project tried to eliminate three hurdles for a widespread adoption of interactive geometry software: the missing interoperability of various software products, the difficulty of searching for appropriate resources, and the lack of a quality assessment process. All these are combined into the Intergeo platform at <http://i2geo.net>, where anybody can find, use, and rate all the resources contributed by the Intergeo consortium, associate partners and the community of dynamic geometry users.

2 About this issue

The articles in this issue, combined from contributions of the I2GEO 2010 conference in Hluboká, Czech Republic,

and contributions by international researchers in interactive and dynamic geometry, give a broad perspective on the resulting field of research. The issue starts with a paper on theoretical perspectives on the creation of suitable content for technology-enhanced learning of mathematics by Allen Leung. The added value of interactive geometry software is a major quality criterion for resources, and it is important to conceptualize the creation of resources that really add value. The quality assessment process and its dual implementation both in the Intergeo platform and in teacher education is described in the following paper of Jana Trgalova, Sophie Soury-Lavergne and Ana Paula Jahn.

Having identified good resources, teachers are encouraged to use and re-use them in their own teaching. They should also alter or, even better, improve them and re-submit them for others. In Intergeo, we tried to measure this appreciated activity, but faced unexpected problems with the notion of re-use. Paul Libbrecht, one of the main architects of the platform, analyzes the difficulties in more detail in his article.

A case study of students working with dynamic geometry resources explains design principles for activities and shows how intricate the analysis of teaching situations is. Using a profound theoretical base, Andrea Hoffkamp analyzes how interactivity can help overcome epistemological obstacles attached to the interpretation of a graph of functions and more generally to the notion of variable and function. The discussion of metavariation gives further insight into ways to help students develop an object view in functional thinking.

Kate Mackrell raises an important point by discussing the enormous complexity of software design for interactive geometry. We see several design decisions that were made differently for each of the software packages discussed. With most standard software today, we are used to the fact that we have to live and can survive with whatever is provided. The situation with interactive geometry software is contrary: Not only are the design decisions important for the intended use in the classroom, but most of the developers of the software are part of the mathematics education community. The in-depth discussion of just a few of these design decisions shows that the community should take advantage of that fact and influence the products that they want to use. Florian Schimpf and Christian Spannagel focus on another aspect of software design, the graphical user interface. Using eye tracking technology, they investigate whether the reduction of graphical user interfaces can help students focus more on mathematics (which is not the case). This article also shows that we should try to validate our approaches with software using methodology from other external but connex sciences like psychology.

Ghislaine Gueudet and Luc Trouche present a project, Pairform@nce, devoted to mathematics teacher education.

In particular, they give a strong theoretical underpinning of their work. Using a documentational approach, they recognize the same paradigm shift from software (or instruments) to resources (or documents) in the Intergeo project and their teacher education project in which teachers need to move from the use of dynamic geometry for doing mathematics to its use for teaching.

The didactic evolution of technology use in the classroom will always be fueled by the advancement of technology. Andreas Fest presents his framework for laboratory-based learning environments. The rapid creation and modification of learning laboratories is a way for mathematics educators to extend the capabilities of dynamic geometry software and to explore new ways of teaching and learning. The work presented connects Intergeo to the research project SAIL-M, where methods of intelligent assessment for mathematics are applied in university level teaching.

The contribution by Philippe R. Richard, Josep Maria Fortuny, Michel Gagnon, Nicolas Leduc, Eloï Puertas, and Michèle Tessier-Baillargeon finally gives a holistic view on educational software development, outlined using the geogebraTUTOR system. Systems that use formal logic or interactive automatic proving are known for several years, with very active research in China. Also, Gerhard Holland created such systems already in the 1980s (Holland & Reitz 1985; Holland 1988). In the article by Richard and others, the dialectic development process of their approach is explained which gives a better insight into the learner model used.

From all articles in this volume emerges the impression of the richness of the field of the use of interactive geometry in mathematics teaching and mathematics teacher education. The Intergeo project could only address a very small part of all the issues involved in this field. The papers formulate new and exciting research questions in

several directions. The need arises to connect mathematics, mathematics education, computer science, and even psychology, if we really want to understand the process of technology-supported mathematics education.

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