

# DESIGNING EFFECTIVE INTERACTIVE TOOLS FOR STUDENTS LEARNING ABOUT GEOMETRIC TRANSFORMATIONS

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**Abstract:** How to conceive educational software in order to enhance learning? The emergent educational technology has brought us a number of tools that makes possible to create multiple pedagogical conditions, encouraging a constructivist approach to learning. The purpose of this paper is to show how to conceive interactive learning tools to generate engaging pedagogical experiences for the learning of geometric transformations at basic school level.

## 1 INTRODUCTION

Educational technology has been undergoing a great development, from a self-directed learning with minimal or no teaching intervention, to highly structured, interactive and collaborative learning environments, which accommodate learning styles not suited to traditional classroom instruction (Wachira, Keengwe and Onchwari, 2008).

A learner-centred approach to these learning environments is turning out to be the best option because it makes possible a large number of interactions. Therefore, teaching with technology changes the role of a teacher as it transforms a teacher-centred lecture to a more constructivist approach (Jonassen, 2000). Constructivism is an educational theory that emphasizes hands-on, activity-based learning throughout which students extend their own knowledge based on their experiences. It can be described with three basic principles:

1) Learners form their own representations of knowledge;

2) Learning is achieved through active experience and also when this experience uncovers inconsistencies between current knowledge and learners' own experiences;

3) Learning occurs within a social context, with interaction with students and other members of the learning community. According to this theory the learner's knowledge is adaptive and the role of

teachers is to challenge the student's way of thinking (Gredler, 2001). In this way, teachers, instead of transmitting knowledge, they become learning coaches, mediating and providing rich environments and learning experiences for collaborative learning (Sharp, 2006).

But how can we apply these principles in the explanation, explorations and use of Geometric Transformations?

According to Rachel S. Smith, to enable learning we must have clear answers to the following questions: what educational involvement are we trying to explain? What do we want to achieve with the application we intend to develop? Every choice made during the design process must refer to the reasons that made us start working in that specific project and to the underlying educational goals. Therefore, we must choose meaningful content that directly supports this goal and present it in appropriate ways. In other words, we need to mobilize syntactic and semantic systems (such as audio, still images, animation, video) chosen according to each situation (Almenara, 2002).

## 2 DESIGNING INTERACTIVE LEARNING TOOLS

Once we have all our ideas well organized and determined the main goals of the project we must pay attention to some instructional design principles.

## 2.1 Instructional Design

When we speak of interactive learning tool one of the first things that come into our mind is the idea of **multimedia**. We can easily understand that it is better to present an explanation making use of two modes of representation, words and pictures, for example, in an appropriate combination and consequently improve conceptual understanding and quality of information processing (Clark and Mayer, 2003). For instance, students who listen to a description of a composition of isometries while also viewing the corresponding animation have a better understanding than those who listen to the narrative without viewing the animation. Users build two mental representations (visual and verbal) and construct connections between them.

Another important aspect to pay attention to is the **contiguity principle**. An explanation containing words and pictures is better understood when they are presented at the same time. Since corresponding words and pictures are in the working memory at the same time, schema formation may take place (Mayer and Moreno, 1997). On the other hand, we must be very careful when combining different forms of speech to avoid **redundancy**. Users learn better from animation and narration than from animation, narration, and text if the visual information is presented simultaneously with the verbal information. This multiple representation increases inappropriate cognitive load (Moreno and Mayer, 2000).

A conceptual distinction should be made between applications that are essentially content delivery (learner's progress through the educational materials in a traditional way) and applications containing interactive exploration (highly interactive, with simulations, games, etc.). This **learner dynamics principle** stresses that simulations can provide goal-based challenges that stimulate user motivation and interest in the material being presented. In addition, providing tools for annotation and collation of notes can effectively stimulate learner engagement (Hede and Hede, 2002).

One more aspect that has a profound effect on the way that learning occurs is related to the structure of the activities proposed. There is no question about the importance of the student feeling engaged with the activities and getting actively involved in the learning process. An interactive learning tool must give the learner the opportunity to solve problems, draw conclusions, compare options, and think about what he/she is doing. For that

reason, the range of activities should address different modalities of learning to contribute to the development of his/her synthesis, analysis, and evaluation skills, always giving the student immediate feedback on his/her progress. The interaction must happen not only between the student and the system, but also between the student and the educator or between the student and other students, in order to facilitate the comprehension and manipulation of the information. This **mediation principle** is an issue we cannot forget while designing an interactive learning tool.

Once the instructional design is well structured it is time to think about the aspect we are giving to the application interface. At this stage of the development we should consider some guidelines Rachel S. Smiths (2004) presents to help us find the balance between the contents and an enjoyable learning experience, in terms of graphic design and usability.

## 2.2 Graphic Design

The **graphic design** of the interface involves a number of choices regarding the layout, colours, navigational elements, and user controls, as it defines the way the user will access the content. Colours and layout should be similar from page to page so that the user understands the navigation and remains interested in the application. But for different sections, as the exercise pages, we must design a contrasting layout, so that the student can tell where he/she is and what he/she is expected to do.

Even though it is widely recommended to keep a clear and simple design throughout the material, Rachel S. Smith stresses that the existence of an element repeated in every page adds interest and continuity. This character becomes the engaging agent that gives rhythm to the action and at the same time gives feedback on the student's performance. Therefore, including **animated agents** in an interactive learning tool is a promising option in the interface development because they allow us to use communication styles which the user is already familiar with.

In the end, if we take these guidelines into account and create a graphically simple and coherent design, combined with some rhythm and contrast, the elements should work together as a whole. If we want to catch the attention of the student more effectively, language is another clue. In fact, **rhetoric** is an expressive element able to produce the desired effect in the student. Using a suggestive

and sometimes risky language intends to persuade him and guide his actions. **Humour** is a good way to cause empathy too and therefore to hold the user's interest. In addition, if we introduce the surprise effect, by changing the logical sequence of the speech and adding unexpected situations, it refreshes the speech and increases its dynamism, relieving some tension from the user. In this case, illustration and animation will assume a leading role during the entire book, by introducing a little nonsense associations and emphasizing some elements. **Metaphors** are also a good option, but must be chosen carefully. Good metaphors generate visible images in the mind so that we can bring them alive by appealing to the student's perception (sight, sound, touch) and stimulating his/her memories. They suggest the familiar and at the same time add a new twist to the action.

But how easy is it to use an interactive learning tool? Can the user easily find what he/she needs or is the interface so distracting that the user has difficulty focusing on the content? Knowing the answers to this type of questions lets us know the **usability** level of the learning tool. The most important is that we do not forget that users must spend their time enjoying learning, rather than figuring out how to use it. The simpler an interface is the more it will improve the learning experience. So, as we already observed, the first step is to create a consistent appearance of the pages in terms of layout, colours, and overall look. Then, all navigational elements must look similar and should be placed in a clearly identified area. And, above all, we must be able to anticipate the user's wants and needs. If the interactive learning tool is easy to understand and to interact with, the student will learn how to use it quickly, and hopefully will make fewer mistakes. Another crucial aspect is to give the student the feeling that he is in control of the application. If it provides a clear navigation and allows the student to stop, restart, skip, or revisit animations and videos, it is more likely that he will explore the application because he knows he will not feel lost. Also, the student should never feel trapped; he should have a clear way out.

### 3 EXPLAINING GEOMETRIC TRANSFORMATION WITH TEXMAT

TexMat is an interactive learning tool designed for 10 to 12-year-old students (following the new

National Curriculum of the Portuguese Basic Education in Mathematics). It accommodates several interesting features, as the Notebook and the Animated Agent, and employs dynamic user evaluation (content and behaviour) in order to allow a dynamic training adaptable to the student's needs. During the development of TexMat the instructional and graphic design principles presented previously have been taken in consideration.

One group of lessons were created under the domain knowledge of planar geometric transformations and will be revealed as an example of pedagogy enhancement in this paper.

As in every lesson, the structure is similar to a traditional book, where the navigation is also made by the turn of pages. Each page represents a different lesson but the layout is coherent to all of them in terms of colour, shapes, typographic fonts and sizes. It has a vertical area for contents that remains identical in the entire book. There is a button area clearly identifiable to access the learning help tools (Notebook, Homework) and the book Units index.

The Mathematical contents are explained to the student textually, usually illustrated by an animation or video to help visualize the concepts, as exemplified in figure 1.

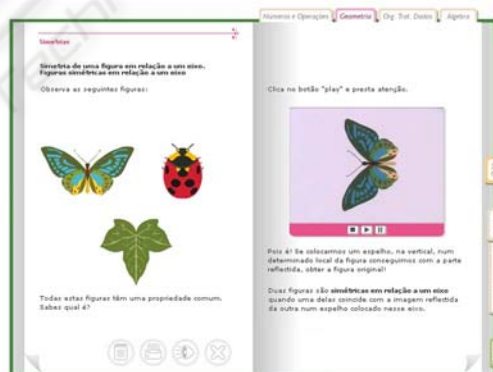


Figure 1: TexMat page with a video explaining the symmetry axis of a butterfly.

As we stated before, if an explanation has words and pictures it is better to present them at the same time. In figure 2 is an example of a lesson on the subject Translations. On the left side there's a written definition of the concept and on the rest of the page are illustrations of real world examples. They are static but once the student clicks *play* they become animated to exemplify the translation movement.

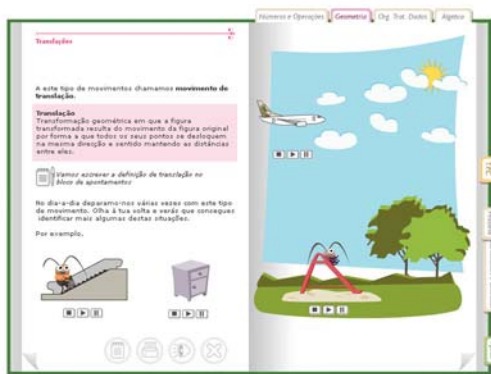


Figure 2: TexMat page with animations showing real-life examples.

However, in case there is an animation or video with audio narration we must hide the text in order to avoid information that is redundant and can cause a visual mess. In a TexMat lesson on the subject Rotations (figure3) we have an audio explanation combined with an animation. Only in the event that the sound of the book is switched off the written explanation will appear.

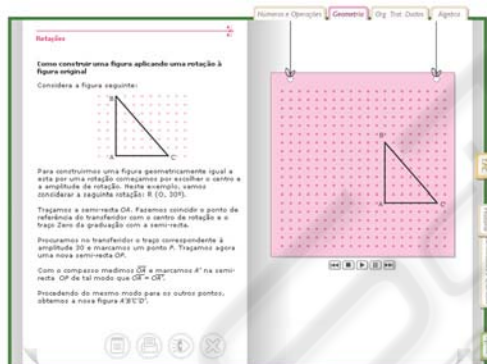


Figure 3: TexMat page with animation: text on the left appears only when sound is off.

During the design of the lessons we always kept in mind the current reading habits of people in general and e-learning students in particular. According to a recent article by Tom Kuhlmann (2008) on the impact that internet has on our reading habits, users are not reading online in the traditional sense, it seems that students are being conditioned to process this information in a different way. In fact, they look at the screen quickly scanning for important information, in a sort of a diagonal reading to find key elements such as titles, highlighted text and pictures. If we make sure these elements are evident then we can build the rest of the contents around them. It is therefore essential to

integrate on-screen text with animation if we want to catch the student's attention and make him/her continue the lessons. As this new digital era is having a strong impact on how people retrieve information we decided to present the contents in TexMat by different steps, one part leading to another instead of explaining the all concepts at once. In figure 4 each definition of the lesson only appears after the previous one has been explained by the animation.



Figure 4: Sequence of events in the same TexMat page.

Also, we tried to avoid a linear presentation in a certain way, as real learning doesn't happen when you give the student information, but when they use it. So this is another important aspect we paid attention to while designing TexMat. In figure 5 of the lesson explaining Reflections, for example, we give the student an interactive application that works like a mirror so that they can try it first, to see how reflections work. Only after he/she has some clues on what reflections are, do we start to teach the lesson.

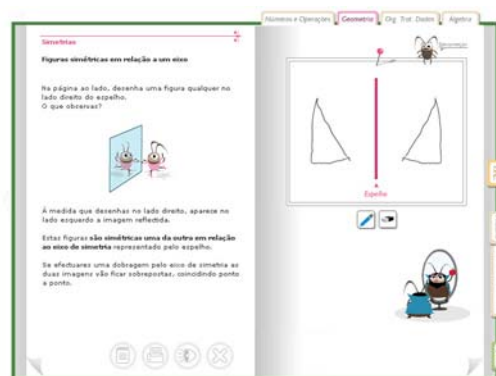


Figure 5: Mirror interactive application on the top of the right page.

Designing an interactive learning tool is a constant challenge to engage students to the developing material; therefore we combined different elements to make the learning more seducing. The Animated Agent that guides the student through the lessons is one example of that. It is a small character that is always on the right side of the book, (see figure 6) giving feedback of the students actions, helping him going through the book.

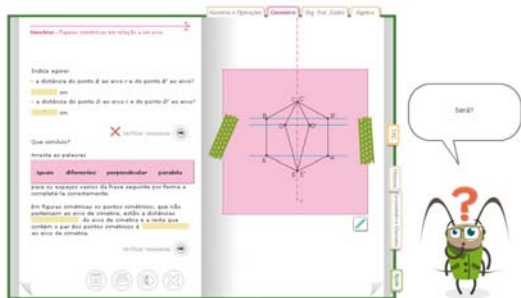


Figure 6: TexMat page with agent giving feedback.

Another feature that we included in TexMat in order to engage the student with the learning experience is the Notebook. With this extra tool the student is able to insert definitions, theorems or formulas building his/her own personal study guide for quick access, which he/she may do whenever he wants to consult, edit or erase information. In figure 7 there is an example of the pre-established contents of Notebook related to its associated lesson.



Figure 7: Notebook appears like a pop-up.

Sometimes throughout the book we introduced funny elements that catch the attention of the student at the same time that assist the explanation. In the lesson presented in figure 5, for example, there are some illustrations and animations added to refresh the speech and increase dynamism.

At the end of each lesson the student has the opportunity to test his/her knowledge or to

consolidate it, if necessary. For that he can access to the section of activities, where he/she will be faced with questions randomly generated and categorized in three classes: **reproduction** (problems whose solution is a direct application of concepts and procedures), **connection** (problems requiring effortless routines involving distinct concepts), and **reflection** (nontrivial problems involving more than one concept). The activity range includes matching exercises, filling spaces, true/false, drawing, constructing figures, and manipulating elements. Once again the graphic design had a crucial role in this section, as it had to differ from the lesson pages. For that we agreed a different layout and a colour scheme going from lighter (class 1) to darker (class3), as we can see in figure 8.



Figure 8: TexMat activity structure.

## 4 CONCLUSIONS

The use of interactive tools for the teaching/ learning of planar geometric transformations can be very successful, since they model in terms of mathematical language the notion of rigid motions which are by its own nature dynamic states. Recall that besides the specific constructed lessons of TexMat, teachers can add their own Geogebra constructions. All the interactivity, randomly generated exercises, and the support of a notebook to obtain additional information, make TexMat a learner-centred approach which invites the student to think and build his/her own knowledge. We believe that this tool makes the learning process clearer, easier, and facilitates the student understanding. Evidences of such affirmation were obtained in a preliminary study with young students, and will be further sustained by future work in classrooms.

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