

Architecture and Teaching: Two Websites Meet

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Abstract

In this paper we present the development of two websites — “Derivando a Matemática” and “Curvas, Superfícies e Arquitetura” — one developed with the goal of creating a source of learning materials for students and teachers of Mathematics and the other to discussing which geometrical curves and surfaces occur in architectural structures — and how they started to collaborate, amplifying the reach of their content.

Introduction

It is not uncommon for students to question the usefulness and applicability of mathematical concepts in everyday life. Even more, given the reality of education in Brazil and other emerging countries, one often finds students who face many obstacles in understanding mathematical concepts. Those can be external factors such as poor teaching quality, lack of school structure and rigid teachers who are too focused on the content, or individual factors such as lack of motivation, learning difficulties, and personal conflicts.

A way to address this problem is to have access to different kinds of content, presenting mathematical ideas in different ways or putting them in context with interesting applications to other areas of life. It is particularly important to have said content easily accessible to a wide audience and in local languages — Portuguese specifically in the case of Brazil.

This paper presents two different initiatives originated within the University of Campinas (Unicamp), in Brazil, at different times. Both started as undergraduate research projects approaching this situation with different lenses, but using the same medium, and eventually joining paths. One (“Derivando a Matemática”) is a website targeted at students and teachers with contextualized presentations of mathematical topics. The other (“Curvas, Superfícies e Arquitetura”) is also a website, but devoted to presenting the different curves and surfaces studied in geometry that find their way into architectural structures.

Curvas, Superfícies e Arquitetura

The website “Curvas, Superfícies e Arquitetura” (Curves, Surfaces and Architecture) emerged as the final product of Vladmir Sicca’s research that took place in the years of 2010-2012 on the broader question of “what are the non-trivial shapes of architectural constructions and why are they chosen?”. Specifically, it aimed at architectural works that have shapes with names in geometry, such as the famous conic sections and quadrics. But it also presents curves and surfaces that have been studied by themselves, typically as solutions to physically motivated problems, such as the catenary, cycloids and others.

The methodology chosen for the study was bibliographical research. At some point it was intended to use some sort of graphical analysis to determine the shapes of at least the curves, but due to the lack of a precise register (usually we have access only to photographs of buildings) and to the difficulties in deciding between similar curves of different nature (see for example the discussion on the Colosseum being an ellipse or an oval in [3]) this direction of research was not pursued. Because of that, only texts explicitly mentioning the nature of the curve/surface of interest were considered.

Still, there are different levels of reliability when texts address the shape of a building. For example, sometimes an arch may be said to be “parabolic”, but that only guarantees that it looks like a parabola, while it might be a catenary or even something else, as is the case of Casa do Lago discussed in the paper [4]. Situations like those highlight the uncertainty that will always be present in this kind of analysis. The choice made in this research has been to register the source of the information on each building and to catalogue the associated information. In addition, register contradicting accounts and value as more reliable registry those discussing not only the curve chosen, but also presenting a sound reasoning behind the choice.

Once the way to approach the problem was chosen, it remained to be decided how to present the results. The research was mainly guided by trying to track the shape of specific architectural features, but also involved gathering material discussing mathematical tools of interest to architects and builders in general. The choice was then to create catalog entries for each building with the geometrical information found and publicize it on the internet. At the time the research started (2010) social media was not as ubiquitous as it is today, so the natural solution at time was to register the research in a website (<https://curvasearquitectura.wordpress.com/>). There, one can find entries for the various buildings and also some accessory information on geometry that is relevant to the topic, mainly descriptions of features of curves and surfaces.

Looking back, it was a good choice, as the website is not restricted from people who do not have social media accounts. The main traffic to the site originates from Google searches for small pieces of the content that are incidentally present in the website, not by people interested in the relationship between geometry and architecture. In fact, unexpectedly around 20% of the site views are on a page that describes how to parametrize an ellipse. This is part of many common courses in Mathematics, but it is harder to find in Portuguese than in English. This engine search-driven dynamic allowed the content to continue to be visited even without updates in the last couple of years. In 2021, the year the site was least visited, it received almost 7,000 visitors, something that would likely not happen if the content was hidden in a social media platform.

Derivando a Matemática

Stephanie Nietto’s website “Derivando a Matemática” (“Deriving Mathematics”) was specifically created with the aim of addressing the challenges students face when learning the subject. It is the result of an undergraduate research project financed by PIBIC (an internal funding program for undergraduate research) at Unicamp starting in 2019. The initial and main objective was to develop an online platform that could make mathematics available in a contextualized way and with a friendlier presentation. It targets both teachers — presenting lesson plans, activity tips for the classroom and examples of ways to approach the content — and students, showing how several concepts are used in the real world in very important applications — both contemporary and historical — in addition to bringing clear demonstrations of well-known topics, such as the Pythagorean theorem, and more abstract concepts, such as the existence of the thirteen Archimedean solids.

With this diversity of content, the website was developed to trigger the curiosity and interest of elementary and higher education students. In particular, it brings to elementary school a large number of activities carried out in the dynamic geometry software Geogebra and, to university students, the much-feared demonstrations. Because of that, the name chosen for the site was “Deriving Mathematics” (available at <http://www.ime.unicamp.br/~apmat/>). The project also involved the creation of a profile on Geogebra where a variety of content can be found at https://www.geogebra.org/u/derivando_a_matem%C3%A1tica.

With the path established, the first step was a search for themes that were common and friendly to content creation, that is, content that could be presented through more dynamic forms of visualization and that would be interesting for the development of teaching activities. Once the subjects were chosen, each page was developed through the reading of textbooks (both aimed at elementary school and at higher education), web pages and the knowledge Stephanie acquired during her own university education.

Often the subject was chosen by influence of topics studied during the university semester. The devel-

oped pages contained interesting mathematical descriptions not previously available online in Portuguese. One example was a page covering the thirteen Archimedean solids (<http://www.ime.unicamp.br/~apmat/solidos-arquimedianos-2/>), that were explored during the course in three-dimensional geometry with the help of Geogebra.



Figure 1: (a) Image of the page "13 Sólidos Arquimedianos no Geogebra" ("The 13 Archimedean solids on Geogebra"). (b) Homepage of the "Architecture" menu.

In addition to the development of thirteen applets, each covering one of the solids, exploratory studies were added to examine prisms, antiprisms, semiregular solids and other elements. Those served as the basis to prove the result that "besides the five regular polyhedra and the two infinite family of prisms and antiprisms, there are thirteen (but for a variant) other semiregular polyhedra". This was accomplished using [2] as a reference and with important help from the instructor who taught the course during the regular semester.

This is one of the examples of content that makes the website such a rich source of information and teaching activities, as in many cases Stephanie herself was in tune with the material being studied and had, as a consequence, a better notion of how to treat the subject. Other important examples are the pages that treat Mathematics from a pedagogical perspective, such as those aimed at teachers in the section "Para professores" ("For teachers"). It is divided in three parts: "Uma palavra sobre ensino" ("A word on teaching"), "Projetos em sala de aula" ("Proposals for the classroom") and "Planos de aula" ("Lecture plans").

The Collaboration Between the Two Projects

One problem with the way "Curvas, Superfícies e Arquitetura" was designed, and one that can be inferred from the dynamic of people reaching the geometry sections that are of greater interest to students, is that the content may not reach instructors, which can be the people who have the abilities and the opportunities to put science outreach material to its best use. Knowing about "Derivando a Matemática" in 2020 presented a very good solution to this problem, as it was a new website with a focus specifically on people preparing classes. A contact with Stephanie and her advisor (Professor Ricardo Miranda) to integrate some topics to their website was made and the idea was accepted with great enthusiasm. A "Mathematics and Architecture" section was created on the destination website to house the material and it was decided that she would choose the content she thought interesting from "Curvas e Arquitetura" and would add it to "Derivando a Matemática".

A way to connect the material would be to link one page to the other, but this would lose people. Also, copying the material and adapting it to the style of the new page gives more resilience to the content. The merging itself was very straightforward, as both pages were developed in the same platform (Wordpress). The fact that the website "Derivando a Matemática" has a considerably larger number of accesses in its two years of existence when compared to "Curvas e Arquitetura" shows it was a good idea from the point of view

of scientific outreach. Also, it was a way to revive the content on the older page as access has been decreasing exactly in the same period that “Derivando a Matemática” was created (see Table 1).

Table 1: *Statistics on the Number of Views of the Websites Since Their Publication.*

	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Curvas e Arquitetura	5,936	14,359	18,591	21,572	22,087	26,721	21,387	15,863	11,041	157,557
Derivando a Matemática							191	47,289	205,430	252,910

The essence of the texts was not changed when migrating the contents from one site to the other, but more dynamic and visual tools were used to make the pages attractive and adjusted to the new website aesthetic.

An example of a page rich in content is the case of “Cycloid in architecture”, which explores the cycloid under various aspects and connects with pages that address topics from Calculus. Here, we carried out a study addressing many facets: the history of the cycloid, its formal definition, physical, geometric and analytical properties, the process of obtaining its equations, arc length and area under the curve and ending with the motivations and applications of this curve in the real world.

This is another case of content rich in possibilities to work in the classroom. The teacher can start the study by the applications, by the history or even by the formal definition. To make the study more interesting, we created a Geogebra applet that integrated directly into the web page for students to manipulate the cycloid while studying its properties. The applet can be animated and shows the case of the elongated cycloid and the reduced cycloid according to the position of point P .

Conclusion

Even with the apparent monopoly of the internet by social media, traditional webpages are a stable, flexible and effective way to spread mathematical material that can be useful for both students and instructors, as the growing numbers of visitors to the websites show.

Of course, projects that aim to create a broad range of relevant material are always being expanded. Our current goal is to migrate more pages from one website to the other in order to reach an ever-growing audience and to create a more complete platform. Both websites have visitors from many Portuguese speaking countries, as well as people we assume are part of the Portuguese speaking community in other places. Our hope is to continue to help and motivate Portuguese speaking students and teachers around the world.

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