

“BIOINFORMÁTICA NA SALA DE AULA”: WEBPAGE TO BOOST BIOINFORMATICS IN THE CLASSROOM

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INTRODUCTION

Bioinformatics has already proved to be a powerful didactic resource which combines an interdisciplinary approach with top-notch scientific research tools (Bloom, 2001; Kovarik et al., 2013; Lewitter & Bourne, 2011; Machluf & Yarden, 2013). In order to boost its integration in middle and high school level, a cooperative path between teachers and research institutions needs to be sharpened (Machluf et al., 2017; Marques et al., 2014; Wood & Gebhardt, 2013). Teachers' training courses are seen as efficient initiatives to foster this networking and an opportunity to depict the main constraints that are preventing teachers from taking full advantage of bioinformatics tools in their teaching practices. International studies have shown that teachers generally claim for training on bioinformatics-based activities curricular framed and for a scientific and technical continuous support. The lack of time available to perform *in silico* activities and language barriers are also underlined by teachers as major constraints that cannot be dismissed when trying to update teaching practices based on bioinformatics approaches (Kovarik et al., 2013; Machluf et al., 2017; Machluf & Yarden, 2013; Wood & Gebhardt, 2013).

In the Portuguese context, biology teachers' self-reflections further sustain the need for bioinformatics-dedicated training courses, the lack of time and the scarce offer of resources in Portuguese language (Marques et al., 2014; Martins, Lencastre, et al., 2020, 2018).

The diagnostic of the constrains that are preventing teachers from implementing bioinformatics-based approaches in their classes shed some light on the interventions that have to be designed. Among the strategies that have been proposed, are the creation of repositories of *in silico*-based activities focused on core competencies in bioinformatics aligned with schools' science curricula (Form & Lewitter, 2011). There are several repositories available online and open source, targeting different learning levels (middle and high school level, undergraduate level) with an offer of teaching resources that can be easily implemented in classrooms, without being an extra burden of work for teachers (European Learning Laboratory for the Life Sciences, 2020; Microbial Life, 2020; NIBLSE, 2020). Furthermore these databases of bioinformatics-based didactics resources are within webpages complemented with glossaries of core concepts, and forums to promote teachers' networking and to expand the interaction among teaching communities (Machluf & Yarden, 2013; Wood & Gebhardt, 2013; Zhang et al., 2007).

Therefore, webpages are extremely useful solutions to centralize the information that educators need and to facilitate networking between teachers and researchers, independently of their geographic location (Barker, 2009; Hakverdi-Can & Dana, 2012; Perrault, 2007). In this scope, the design of the webpage "*Bioinformática na Sala de Aula*" appears as a corollary of an effort to scaffold Portuguese science teachers to integrate bioinformatics in their practices, by meeting their reported needs, and to promote the use of open access bioinformatics resources with intuitive interfaces, inviting teachers to explore innovative and motivating pedagogical practices in formal and informal teaching contexts.

METHODOLOGY

The webpage design

The webpage (<https://bioinformaticaaula.wixsite.com/bioinformatica-pt>) was designed taking into account the main constraints to integrate bioinformatics in the classroom identified by teachers, namely time, language and the need for more training to improve their background on bioinformatics (Martins, Lencastre, et al., 2020).

To avoid time-consuming procedures to prepare and implement bioinformatics-based activities in the classroom, a portfolio of dry lab resources was compiled and made available in the webpage, organized according four main themes: *Molecular biology: in silico analysis* (Theme 1); *Lac operon: gene regulation and evolutionary relationships* (Theme 2); *Exploring metabolic pathways across the different life domains* (Theme 3); and *Bioinformatics in service to the population – practical examples* (Theme 4). All the resources were validated by in-service science teachers and, part of them, implemented in both formal and informal educational contexts in order to validate their impact on students' scientific and digital literacy, interest and attitudes (Martins, Fonseca, et al., 2020, 2018; Martins, Lencastre, et al., 2018). There are three main reasons behind the scientific topics chosen: firstly, they are related with students' pre-existing knowledge; secondly, the topics chosen drive to a meaningful introduction of new core concepts, enhancing students' literacy; and thirdly, the four thematic issues contribute to overcome students' misconceptions, namely the use of gene and genome as synonyms or misinterpretations regarding gene regulation (Form & Lewitter, 2011; Lewis & Kattmann, 2004; Martins, Fonseca, et al., 2020; Martins & Tavares, 2018; Shaw et al., 2008).

The webpage, written in Portuguese, consists of an Welcome Page (Página Inicial); Exercises (Exercícios) supported by guidelines and Power Point presentations; Supplementary

Materials for Teachers (Materiais de Apoio ao Professor); a dedicated section for Training Courses' information (Cursos de Formação); a Forum (Fórum); details regarding School Partnerships (Escolas Parceiras) and About the team (Sobre Nós) (Fig.1). The webpage has been continuously updated in order to answer teachers' requests, and spread by partners such as Casa das Ciências and CIBIO – Research Centre in Biodiversity and Genetic Resources - InBIO Associate Laboratory through their webpages (Casa das Ciências, 2017; CIBIO-InBIO, 2020).

WEBPAGE CONTENTS

Welcome Page (Página Inicial)

In the welcome webpage (Fig.1) the reader finds a brief description of the potential of bioinformatics as a didactic tool, supported by relevant state-of-the-art literature, and an explanation about the rationale behind the creation of the webpage “*Bioinformática na Sala de Aula*”.



Figure 1. Layout of the Welcome Webpage.

Exercises (Exercícios)

Exercises section compiles a portfolio of bioinformatics labs framed in the curricula, with detailed guidelines and Power Point presentations for their implementation, organized on four main topics (Theme 1 – Theme 4) (Fig.2).



Figure 2. Overview of Exercises section.

The rationale to select the topics was grounded on their relevance according to the science curriculum and also having into consideration their potential to dismiss students' specific misconceptions. In this regard, *Molecular biology: in silico analysis* (Theme 1) uses the bioinformatics platform "In silico simulation of molecular biology experiments" (Bikandi et al., 2004; Millán et al., 2013), to perform analysis of restriction enzymes, as well as to simulate *in silico* experiments of Polymerase Chain Reaction (PCR). Although the potential of this platform is broader, emphasis is given to two applications that meet the requirements of the school curricula: i) Amplification by PCR to reconstitute and confirm *in silico* a diagnostic experience of pathogenic bacteria reported in a scientific article; and ii) The elaboration of restriction maps of bacteria genomes using different restriction enzymes. Theme 1 exercises are also dedicated to explore DNA sequence analysis tools of the National Center for Biotechnology Information

(NCBI) to identify putative genes (Martins, Fonseca, et al., 2018; NCBI Resource Coordinators, 2018).

Theme 2 – *Lac operon: gene regulation and evolutionary relationships* – was set up to acknowledge *lac* operon, an example frequently displayed in textbooks to approach gene regulation, and aware of its potential for comparative genomics studies. Framed within this theme, NCBI ORFfinder tool is used to identify start codons, namely alternative codons, and also to explore specificities of the bacterial genetic code (Martins, Fonseca, et al., 2018; NCBI, 2020). Microbial Genome Annotation & Analysis Platform (MaGe) is used to make evolutionary assumptions through comparative genomics (Vallenet et al., 2013). These exercises have been shown to benefit students learning regarding genomics-related concepts, as well as to update the currently taught notions (Martins, Fonseca, et al., 2020; Martins & Tavares, 2018).

In order to approach metabolic pathways using bioinformatics tools, Krebs cycle was the topic chosen for theme 3 – *Exploring metabolic pathways across the different life domains* – having in mind that it is a core concept of science school curricula. Within this theme, the exploration of the MetaCyc - Metabolic Pathway Database tool allows to study Krebs cycle and gives a valuable contribution to understand the amphibolic character of its intermediate compounds involved in other reactions of cellular metabolism (Caspi et al., 2017). In addition, in theme 3 an exercise is dedicated to study a biomolecule present in human metabolism – cholesterol, using HumanCyc - Encyclopedia of Human Genes and Metabolism (Romero et al., 2005). This platform makes possible to analyze in detail the metabolic pathway that gives rise to it, while recognizing other associated compounds that assume a crucial role in the human body (example: in the production of vitamin D). Furthermore, students' awareness of the

connections between the biosynthesis pathways of different biomolecules, besides its scientific value, may be an endorser for the adoption of healthier behaviors.

Within Theme 4 – *Bioinformatics in service to the population – practical examples* (Fig.3), bioinformatics labs were optimized to stress the importance of predictive bacteria growth models in food matrices, which is a subject particularly suitable for both middle and high school students, that when combined with wet lab procedures, can positively impact students’ literacy on food preservation techniques and enhance their motivation as previously showed (Martins, Lencastre, et al., 2018).



Figure 3. Resources for teachers to address theme 4.

At the bottom of the webpage “*Bioinformática na Sala de Aula*” (<https://bioinformaticaaula.wixsite.com/bioinformatica-pt>), there are several documents with tips and suggestions for teachers to implement the activities in their classes, such as the clarification that all the platforms and tools proposed to use are open access and the suggestion that some platforms as NCBI can be faster accessed during the morning in Portugal, mainly due to the time zone difference with countries where the number of researchers connected increase considerably during the afternoon. The link to the forum and to the main contact is also described in this section of the webpage, aiming to set an easy-going way for teachers to ask for support.

Supplementary Materials for Teachers (Materiais de Apoio ao Professor)

This section provides information that will assist teachers in implementing bioinformatics exercises, namely bibliographic references or information related to the contents approached in the bioinformatics labs such as genetic code, synteny or open reading frames (ORF) (Fig.4). This section is continuously updated in order to answer and clarify any questions that may arise, and that may be shared on the forum.

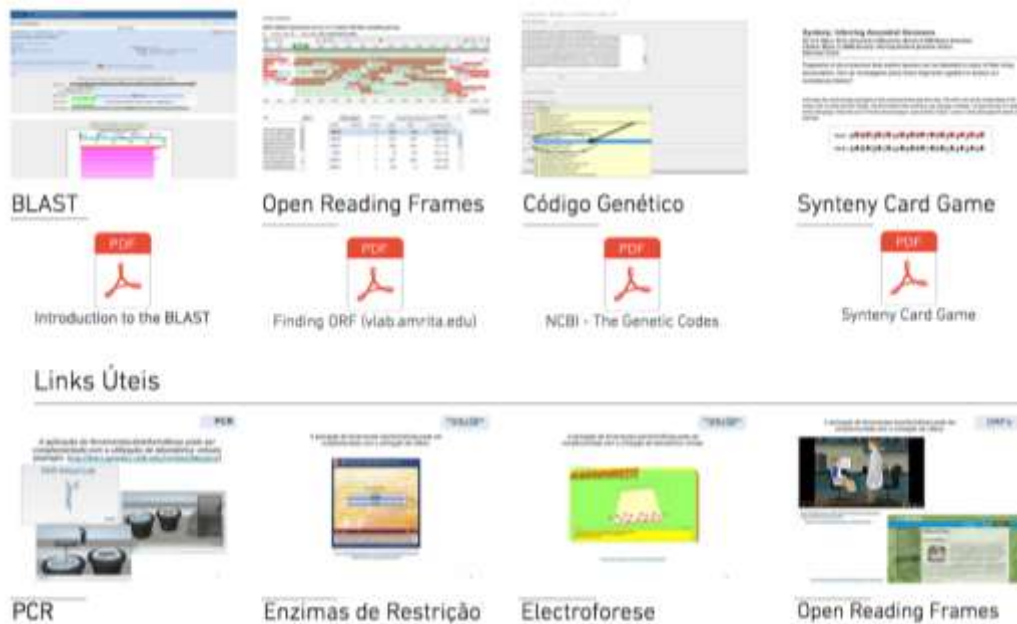


Figure 4. Extra documents and useful online resources for teachers are provided to explain genomics core concepts.

Training Courses (Cursos de Formação)

A dedicated area for training courses is reserved to the dissemination of information. In the example below (Fig.5), a section with exclusive access for the participants of the training course was created in order to share the guidelines of the course, as well as the projects produced by teachers, namely the training course assessment document. The sharing of these documents was provided after teachers' approval.



Figure 5. The webpage is also a channel of dissemination of bioinformatics training courses for teachers.

Forum (Fórum)

A forum (Fig.6) for sharing experiences, opinions, questions and comments is a privileged communication channel to boost collaborative work, encourage discussion of ideas and scaffold teachers.

Fórum Bioinformática na Sala de Aula



Número total de visualizações de página

148

Páginas

• Página Inicial

sexta-feira, 10 de fevereiro de 2017

Vamos começar?

Aqui poderá partilhar opiniões, comentários e questões sobre as atividades de bioinformática, a sua implementação e não só! Sempre que alguma dúvida surja poderá aqui partilhá-la e nós iremos ajudar.

Figure 6. Forum interface.

School Partnerships (Escolas Parceiras)

Partnerships section includes information regarding the schools that collaborated with the research group namely by allowing the implementation of some activities, such as “Mining the Genome: Using Bioinformatics Tools in the Classroom to Support Student Discovery of Genes” (Martins, Fonseca, et al., 2018). In order to publish school logos (Fig.7), an authorization was obtained from each school directive board.



Figure 7. School partnerships.

About (Sobre Nós)

In this section, it is possible to obtain direct contact with the research group, as well as more detailed information about the team and the research aims of Microbial Diversity and Evolution (MDE) group from CIBIO-InBIO and hosted at Faculdade de Ciências da Universidade do Porto (FCUP) (Fig.8).



Sobre Nós

Este website surgiu inserido no âmbito do projeto de doutoramento "Integrating bioinformatics at the interdisciplinary intersection of elementary and secondary curricula using a bottom-up approach" (SFRH/BD/112038/2015) financiado pela Fundação para a Ciência e a Tecnologia (FCT).

Este projeto tem como objetivo integrar a Bioinformática na Sala de Aula nos diferentes níveis de ensino, através de intervenções em parceria com os docentes, alunos e a comunidade educativa. Este projeto está a ser desenvolvido na Faculdade de Ciências da Universidade do Porto no grupo de investigação *Microbial Diversity and Evolution (MDE)*, que integra o CIBIO - Centro de Investigação em Biodiversidade e Recursos Genéticos/InBIO Laboratório Associado.

Fernando Tavares

Ana Sofia Martins

Clique para saber mais sobre a equipa

Figure 8. Details for contact are provided to the visitors.

DISCUSSION

As previously mentioned, this webpage is focused on meeting Portuguese teachers' needs to implement bioinformatics in their schools. Despite the guidelines of the bioinformatics labs have been addressed in schools and validated for in service teachers, no formal assessment of the use of this webpage by teachers was performed yet. Nevertheless, some considerations can be drawn such as the accesses to the webpage. It could be noticed that between 2017 and 2020, the access was biased by teachers who attended bioinformatics training and who had direct contact with the team of the project. Thus, the accession of this tool was not so frequent as desired, highlighting the need to disseminate the webpage using more proficient strategies.

Designing an *e-learning* training course in which teachers have to access the webpage to accomplish specific tasks such as download the handouts, contribute with information as “wikis” or podcasts or to use the forum to register comments and doubts as a blog, should be thought as webpage promotion strategies (Kamel Boulos et al., 2006; Richardson, 2010; Wheeler & Wheeler, 2009).

Linked with the need to improve dissemination strategies, is the design of a research plan to evaluate the impact of the webpage on teaching practices. In the future, web-based portfolio entries analysis (Oner & Adadan, 2011), online discussions on a private listserv complemented with attitude surveys (Koszalka, 2001), questionnaires based on models of technology acceptance (Akpınar & Bayramoglu, 2008; Liaw, 2002), that can also be online (Yuen et al., 2011), are reported strategies that can be taken into consideration to effectively depict the webpage impact and to overcome the constraints pointed out by teachers in promoting bioinformatics-based learning.

CONCLUSION

“*Bioinformática na Sala de Aula*” is a portfolio of resources validated as suitable didactic instruments and ready to be used by teachers in the classroom. Activities handouts are in Portuguese and the topics approached are framed according to the Portuguese science curricula, focus on contents particularly addressing students’ difficulties or misconceptions. The webpage is also a repository of genomics and bioinformatics-related information for teachers, being a complete source of information. Communication channels between researchers who use bioinformatics and teachers are also provided in the webpage through a discussion forum for teachers to feel continuously supported.

Overall, we believe that “*Bioinformática na Sala de Aula*” may bring to the spotlight the educational benefits of bioinformatics as a didactic tool, capable to enhance the scientific and digital literacy of future active participants in society, i.e. students.

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