BRINGING BIOINFORMATICS TO SECONDARY EDUCATION: A WORKSHOP FOR SCIENCE TEACHERS

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Having in mind the technological world we live in, scaffolding teachers to integrate computer-based resources in their classes is an important endeavour when it comes to teacher professional development. In this context, a workshop on bioinformatics to address gene regulation, molecular biology and genomics in high school gathered a group of 18 high-school science teachers. Following the workshop, the participants answered a questionnaire aiming to diagnose teachers' perceptions about bioinformatics; to identify the main constrains that are preventing teachers from successfully implementing bioinformatics in their classes; and to evaluate the potential to integrate basic bioinformatics exercises in their educational practices. Data were subjected to descriptive statistics and to content analysis. The results showed that the teachers attending the workshop were highly motivated and interested in learning more about bioinformatics and about strategies to integrate bioinformatics in their classes. Despite teachers highlighted the adequacy of bioinformatics to the educational context, most of them mentioned that their academic background was not sufficient to confidently implement bioinformatics-based exercises in their classes. Teachers claimed for more training courses in this area and approximately half of the participants admitted that schools are equipped with the necessary resources to integrate bioinformatics. Overall, this study emphasizes the importance to foster more initiatives to integrate bioinformatics in secondary education curriculum and highlights the need to increase the offer of teachers' training on bioinformatics.

Keywords: Computer Based Learning, Teacher Professional Development, Technology in Education and Training

INTRODUCTION

Despite technology is now acknowledged as a helpful tool for teaching and learning science, many science teachers got their academic qualifications for teaching at a time in which technology, namely computers, were rarely used or inaccessible for most of the people. It is therefore with no surprise that in-service teachers feel uncomfortable or not motivated to use computers in their classrooms, being urgent to scaffold teachers to develop their Technological Pedagogical Content Knowledge (TPACK) (Koehler & Mishra, 2009; Mumtaz, 2000).

Having this need in mind, professional development programs for science teachers should focus on helping them to integrate the use of the technology in the teaching practices. An opportunity to integrate computers and digital resources as a didactic tool based on real research procedures is to approach genomics and molecular biology based-on bioinformatics

tools (Chiovitti et al., 2019; Gelbart & Yarden, 2006; Martins, Fonseca, & Tavares, 2018; Nunes, Júnior, Menezes, & Malafaia, 2015). Despite genomics being one of the most important revolutions of late 20th century and at the beginning of this century, the lack of literacy on genomics and molecular biology in the general population is reported in several studies (Eklund, Rogat, Alozie, & Krajcik, 2007; Kirkpatrick, Orvis, & Pittendrigh, 2002; Kolarova, 2011; Lock, 1996; Tarver, 2010). While an effort is being made to integrate bioinformatics in high-school science curricula in different countries, it is unquestionable that more teacher's training opportunities in bioinformatics is needed (Attwood, Blackford, Brazas, Davies, & Schneider, 2017; Kovarik et al., 2013; Machluf, Gelbart, Ben-Dor, & Yarden, 2017; Marques et al., 2014).

In this context, the workshop "*From DNA to Genes and to Comparative Genomics: Bioinformatics in the classroom*" was aimed to instruct science teachers about the suitability of bioinformatics activities to their teaching practices. Teachers were challenged to explore bioinformatics-based exercises particularly chosen to teach basic molecular biology concepts, to address gene regulation and to discover the usefulness of comparative genomics (Martins, Fonseca, & Tavares, 2018). This training workshop on bioinformatics allowed to boost teachers' TPACK, since teachers developed their technological knowledge by learning how to use bioinformatics tools and, concomitantly, they enlarged their pedagogical and content knowledge, by discussing new strategies to teach curricular contents and additionally introduce key concepts in genomics such as Open Reading Frame (ORF) or Basic Local Alignment Tool (BLAST) (Martins & Tavares, 2018). The workshop was promoted in the context of an international meeting for teachers (Casa das Ciências, 2018) that occurred in Portugal in 2018.

OBJECTIVES

The main objectives of this study were to diagnose teachers' perceptions about bioinformatics; to infer the potential of its integration in educational practices; and to identify the main constrains that are preventing teachers to successfully implement bioinformatics in their classes.

RESEARCH QUESTIONS

This study was driven by two main research questions: "*Which are the teachers' perceptions about bioinformatics and its integration in science teaching practices*?" and "*Which are the main constrains that are preventing teachers from integrating bioinformatics in their teaching practices*?"

METHODS

Participants

The sample included 18 science teachers (14 female and 4 male) from 14 different schools that voluntarily enrolled at the workshop. Seven of the 18 teachers hold a master's degree. Participants have an average of 26.61± 7.48 years of teaching experience. Between 2016 and 2018, 4 teachers taught at elementary school level (students between 12-15-year-old), 6 taught at secondary school level (students between 16-18 years old) and 8 taught both elementary and secondary school levels.

Materials

Framed within the curriculum for biology in secondary education (Council, 2013), the four hours workshop "*From DNA to Genes and to Comparative Genomics: Bioinformatics in the classroom*" drives teachers to explore the potential of bioinformatics as a didactic tool to approach contents, such as the organization and regulation of genetic material, and to carry out evolutionary inferences. From an *in silico* analysis of a DNA sequence it is proposed to identify genes and to determine the putative functions of their products. Additionally, using comparative genomics platforms such as *MaGe – Magnifying Genomes* (MicroScope), the participants were challenged to evaluate the presence of certain genes in different taxonomic groups aiming to infer evolutionary relations. This activity contributes to a holistic approach to genomics, genes and proteins, as well as to propose evolutionary hypotheses (Martins, Fonseca & Tavares, 2018). Each teacher was asked to bring their personal computers to carry out the exercises.

To diagnose teachers' perceptions about bioinformatics and its integration in science teaching practices as well as to identify the main constrains that are preventing teachers from integrating bioinformatics in their classes, a specifically designed questionnaire, adapted from the survey previously described by Martins, Lencastre and Tavares (2018), was implemented. The questionnaire, including 35 questions in various formats, namely dichotomous, Likert-type (ranged from 1 to 5) and open-ended questions, and is divided into three parts: *Part A*: socio demographic data; *Part B*: assessment of teachers' training and academic background on bioinformatics, and appraisal of teachers' attitudes towards bioinformatics integration and of their perceptions regarding workshop attendance; *Part C*: teacher's opinions about the questionnaire: objectivity, comprehension of the items, and suggestions.

In Part B, questions were designed according to the objectives defined for this study. Questions 1 and 5 (Q1; Q5) were aimed to diagnose teachers' definition of bioinformatics as well as to characterize the importance of bioinformatics to the current research. The assessment of teachers' interest and perceived knowledge about bioinformatics were addressed through questions Q3, Q12.1., Q12.2. Another dimension evaluated was teachers' perspectives on the importance of integrating bioinformatics in their teaching practices as well as to identify the main obstacles to this integration. In this regard, questions Q2, Q6, Q7, Q9, Q9.1., Q9.1.1., Q10, Q11, Q12.3., Q12.4. were included in the questionnaire. Question Q8 was intended to characterize the use of technology in the classroom by teachers. Lastly, and having in mind the main findings of previous studies highlighting the importance of promoting teachers training actions in the area of bioinformatics (Machluf et al., 2017; Machluf & Yarden, 2013; Martins, Lencastre, & Tavares, 2017, 2018), questions Q4.1., Q4.2., Q12.5., Q13, Q14, Q15, Q16 and Q17 were introduced to characterize the impact of the workshop on teachers perceived knowledge about bioinformatics as well as to evaluate the workshop, identifying the potential of the action but also having feedback on possible improvements.

Teachers rated the questionnaire as an objective instrument (4.76±0.44) and easy to understand (4.76±0.44). One participant added the following suggestion for improvement: "*In question 12.4., you should specify if the classes are lectures or if they are practical classes of biology*

including wet lab and experiments". This suggestion will be taken into consideration in future questionnaires.

Data Collection and Analyses

The questionnaire was implemented after the attendance of the workshop, i.e. when participants finished the proposed exercises. The aims of the research as well as the objectives of the questionnaire were explained to teachers who voluntarily agreed to answer the survey. Descriptive statistical analysis was performed for quantitative data (Punch, 2009). For qualitative data, a thematic content analysis of the participants' responses to open-ended questions was carried out (Roberts, 2015; Schuster & Weber, 2006).

RESULTS AND DISCUSSION

Teachers' background on bioinformatics

The majority of the teachers (94.44%) correctly defined bioinformatics (Q1), and one teacher mentioned that bioinformatics is "*a didactic tool for science classes*". Among all listed notions (49), teachers mentioned frequently the following: informatics (12.62%), biology (8.74%), data (6.8%), tools (6.8%) and applications (4.85%). This analysis revealed that teachers recognized the scope of bioinformatics as the scientific field which develops or uses tools and applications of informatics to understand the biological data, which fits well with a general definition of bioinformatics (Luscombe, Greenbaum, & Gerstein, 2001; Sadek, 2004).

Teachers revealed to be interested in bioinformatics (Q3) and recognized its importance for scientific advances (Q5) (Figure 1). However, teachers considered that their academic background is not sufficient to feel prepared to teach using bioinformatics tools (Q12.1.) and highlighted the added-value of professional training (in-service) (Q12.2.) to implement bioinformatics activities in their classes (Figure 1). These results are in line with the literature (Machluf, Gelbart, & Yarden, 2012; Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018; Wood & Gebhardt, 2013) and reinforce the importance of promoting initiatives of professional development oriented for bioinformatics training.

Attitudes towards bioinformatics integration

The importance of integrating bioinformatics in elementary (Q6) and secondary education (Q7) was highlighted by the participants (Figure 1), as well as the potential to use bioinformatics both at Biology classes and Information and Communications Technology (ICT) classes (Q2), mentioned by 77.78% of the teachers. It is acknowledged that bioinformatics-based activities foster students' hybrid abilities in computation and biology, nurturing a wide range of skills such as using bioinformatics to find, retrieve and organize data by identifying an appropriate data repository, to understand evolutionary related processes or to develop their critical thinking namely in which concerns open data access (Foster & Sharp, 2007; Mariano, Martins, Santos, & Minardi, 2019; Oliver et al., 2012; Sayres et al., 2018).

The majority of teachers (94.44%) assumed to use computers to explore online resources in their classes (Q8), but only 5 out of 18 (27.78%) revealed to have autonomously explored bioinformatics resources in order to implement them in their classes (Q9). Among the teachers who had previously explored bioinformatics resources, 3 out of 5 (60%) actually implemented

the activities in their classes (Q9.1.). The two teachers who did not (40%), listed as the main reasons "*Lack of computers available*" and "*The need to better understand the explored bioinformatics tools".* However, their intention is *"to apply the activities in the classroom soon*" (Q9.1.1.).

Around half of the participants (55.56%) considered that the school/institutions where they were teaching have the necessary conditions to integrate bioinformatics-based activities in their classes (Q11), which is in agreement with recent reports indicating that most schools in Europe are equipped with technological devices (European Comission, 2013). In contrast with this result, the main constrains identified by teachers to carry out the implementation of bioinformatics activities in the classroom (Q10) were: computers (7.87%) and internet (6.74%). Only 2 out of 18 teachers (11.11%) revealed positives attitudes regarding the possible constrains that can arise when implementing bioinformatics in their classroom mentioning that "*cannot identify any constrains. The school has the necessary resources (…) and students are motivated*" and "*the management of the time is possible especially in the 11th grade*". 66.67% of the participants indicated that the main constrains to implement bioinformatics-based activities in their classrooms were related with logistics aspects (resources and time) answering that "*computers are lacking in schools*"; "*the number of students per class is too high*"; "*the internet connection is weak*"; and "*bioinformatics resources are not in Portuguese*". Teachers mentioned that schools are well prepared to carry out bioinformatics exercises, however logistics aspects were mentioned as the main hinder to not apply these tools in the classrooms. This result stresses the importance to better characterize schools' reality in which concerns technology use.

16.67% of the participants identified both logistic constrains and lack of teacher's confidence as the main difficulties to implement the proposed approached in the classroom. Teachers emphasized their lack of confidence to approach some curricular topics using bioinformatics resources and highlighted their need to acquire specific training, which is corroborated by other studies (Cebesoy & Oztekin, 2018; Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018). One teacher (5.56%) mentioned that "*The complexity of some processes and their interpretation by the students requires strong orientation and motivation, which should be taken into account when organizing the activity.*" This perspective was included in category: Constrains related with the student's performance.

Furthermore, the data showed that teachers considered that planning and implementing bioinformatics-based activities is more time-consuming and requires more resources than other activities (Q12.3.; Q12.4.) (Figure 1). These notions can be related with the lack of opportunities for teachers' training in bioinformatics. Training is crucial for teachers to feel more acquainted with bioinformatics tools and to clarify that planning and implementing bioinformatics-based activities can be framed within the time schedule for a class (90 minutes) as described by Martins, Fonseca and Tavares (2018). Another reason that can explain this result is the absence of didactic bioinformatics resources in Portuguese. In fact, the idiom of the majority of the platforms and of the exercises available is English which was previously reported as a barrier to non-English speakers (Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2017, 2018). This result highlights the importance of creating a portfolio of

bioinformatics-based activities, in this case adapted to Portuguese, and making it available for the educational community in other to emphasize the adequacy of integrating bioinformatics in educational approaches.

Perceptions regarding workshop attendance

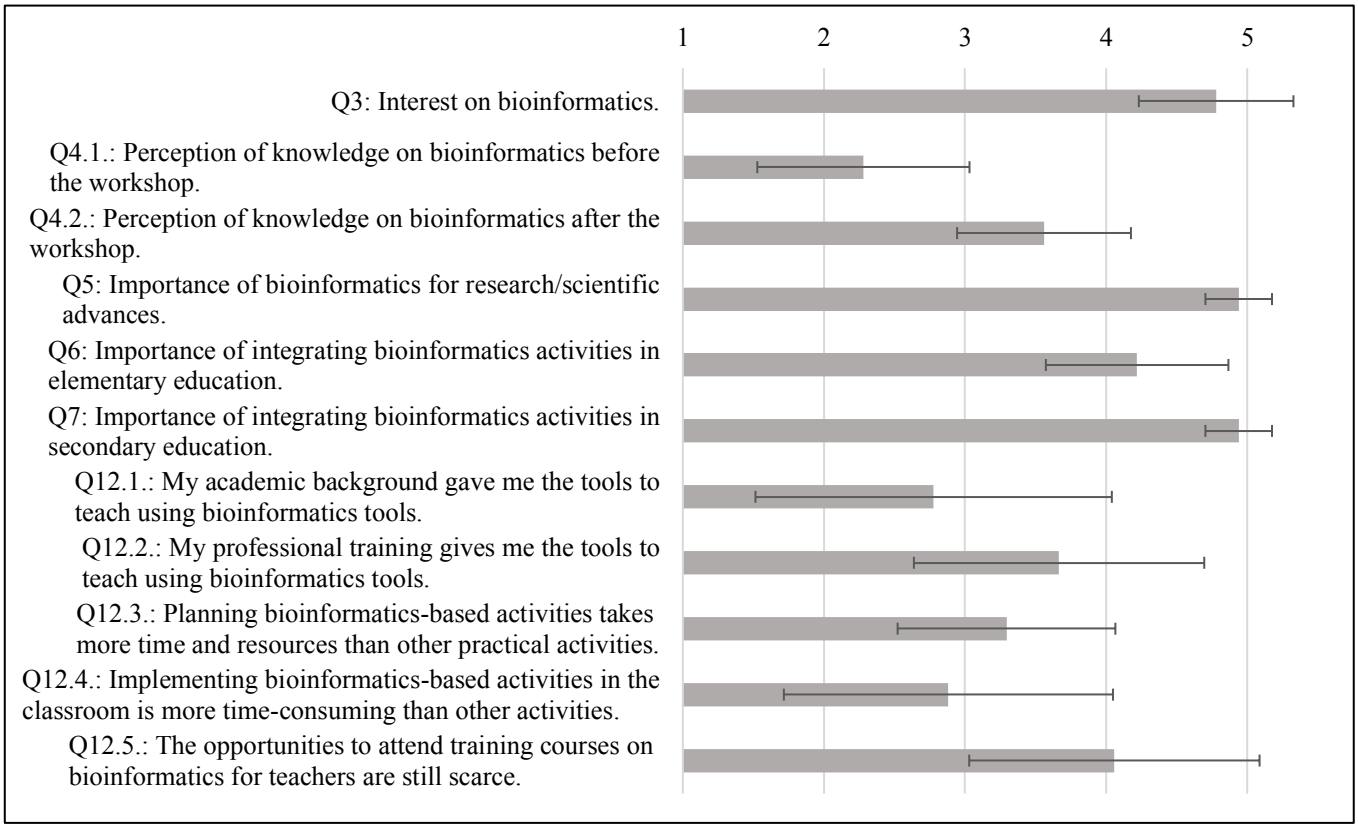
A careful analysis of teachers training on bioinformatics was carried out having in consideration the previous results reported by Martins, Lencastre & Tavares (2017, 2018), by Machluf et al. (2012, 2013) and by Marques et el. (2014). Despite the interest of all the participants in attending training courses on bioinformatics for teachers (Q16), it was mentioned that the availability of these courses is still very scarce (Q12.5.) (Figure 1). In fact, the importance of adequate teachers training in this scientific field, is further supported by the higher perception teachers have about their knowledge in bioinformatics after attending the workshop (Q4.2.), in comparison with that perception before the workshop (Q4.1.) (Figure 1).

Regarding the workshop itself, teachers were asked about the reasons that motivate them to attend this workshop and to choose this workshop among others (Q13). They were asked to list the main difficulties found when they were performing the workshop activities (Q14) and suggestions were collected in how to improve the workshop (Q15).

The 18 participants listed the main reasons that motivated them to attend the workshop (Q13). By carrying out an analysis of the five most frequent words mentioned, it was possible to list: class (6.84%); application (5.98%); classroom (5.13%); learn (4.27%); and utilization (4.27%). This general analysis suggests that teachers wish to learn how to apply and how to use the bioinformatics tools in their classes. Adding to this analysis, it was possible to identify three main categories of answers. "*To learn to apply*" – was mentioned by three participants (16.67%). These participants revealed that they chose this workshop in order to learn "*how to implement the tools of these area*" in their classrooms. Six out of the 18 participants (33.33%) highlighted as the main reason to attend this workshop "*Curiosity*". Teachers justified their attendance as an opportunity to learn more about bioinformatics, by curiosity and because they were "*interested in related topics such as genetics and all the fields that are related with DNA*". This result reinforces teachers' interest in this scientific topic. The third category is particularly important in the context of this study: "*The need of updating*". Mentioned by 9 participants (50.00%), this category included answers such as "*I felt the need of learning about this area* (…) *and to explore bioinformatics in a scientific and right perspective*" or "*I urgently need to improve my skills* (…) *to follow the quick development of these applications* (…) *and to implement them with my classes*". This result is in line with the considerations about the urgency of training courses reported above. Teachers are interest in this scientific area and the adequacy of the proposals to the schools is recognized, although they do not feel prepared to proceed with the implementation of the tools without previous specialized training (Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018; Shuster, Claussen, Locke, & Glazewski, 2016; Wood & Gebhardt, 2013).

In which concerns with the main difficulties found by the participants while performing the activities of the workshop (Q14), three categories of answers were defined. 50.00% of the participants (9 out of 18) listed as the main difficulties' technical aspects such as internet access, and the lack of time or difficulties to read the paper version of the guidelines. In fact, these constrains were related with the organization of the workshop itself and not with difficulties related with the bioinformatics-based activities performed. However, the internet connection was fixed even during the workshop and the digital version of the guidelines was sent by email to the participants. In this regard, we can assume that the logistic constrains were solved and the workshop work-flow was not affected. Two out of 18 participants (11.11%) revealed to have difficulties in interpreting "*aspects associated with gene sequences/nucleotides*" and to "*understand the steps to follow*". In contrast with these results, 38.89% (7 out of 18) reported no difficulties and one teacher did not answer this question.

Figure 1. Answers given by participants according to a Likert Scale (Range 1 to 5). Grey bars represent the mean value and the error bars refer to the standard deviation.



Finally, suggestions for workshop improvement were asked to the participants (Q15). 44.44% of the participants did not answer this question. 33.33% of the participants listed suggestions for improvement. Essentially participants claim for: "*More exercises*"; "*I would like to attend a training course (longer) in this area, once 3 hours are not sufficient to understand all the information discussed*"; and "*to increase the font size of the text in the guidelines – paper version*". 22.22% highlighted that "*do not think that the workshop needs to be changed*".

CONCLUSION

Teachers revealed to be interested in bioinformatics and recognized its importance for scientific advances, which is in frame with the expected teachers' perceptions about bioinformatics as a scientific discipline. Teachers were open and motivated to integrate bioinformatics in their teaching practices. Regardless their will, teachers believe that key constrains have to be overcome, emphasizing the need of suitable training through dedicated courses. Thus, the main take-home message from this workshop is the urgent need of training courses for teachers in order to fuel the integration of bioinformatics in the curriculum and education daily practices. Adding to this, it is important to better understand the reasons why teachers admitted that their schools have the necessary conditions to implement bioinformatics-based approaches, but contradictorily they indicated as the main constrains to this implementation: poor internet connection and lack of computers. A reedition of the workshop occurred in July 2019 with 40 participant teachers. In this workshop, new data were collected in order to increase the robustness of this study. Adding to this, a website is under construction and will be soon available for teachers, with bioinformatics-based exercises in Portuguese in order to meet the participants request of having more available resources in their native language.

We believe that the current study is a wakeup call for educational stakeholders to boost bioinformatics educational integration aiming to meet the challenges of a society capable to understand the scientific advances and take informed decisions.

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