Bioinformatics Curriculum: A Comparative Analysis in Pakistani Perspective

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Abstract Bioinformatics has been a hot topic in Pakistan to be a separate and vital field of study. There has been a sudden increase in the Bioinformatics courses for both undergraduate and graduate degrees. The courses selected in this study four years bachelor degree and two year master degree of full-time study, each of these courses dissecting into six categories as: Bioinformatics, Biological Science, Mathematics, Statistics, Computer Science and Elective subjects, to determine where the differences lie. This study reviews state-of-the-art Bioinformatics education in Pakistan, compares it with global standards and initiatives and proposes a set of recommendations to be integrated in the national educational framework of curriculum and policy making.

Keywords Bioinformatics, Global Standards, Undergraduate, Educational Framework, Curriculum, Graduate

crucial portion of the curriculum, which would be a set of core Bioinformatics courses that build upon the contributing disciplines to present the basic intellectual structure of the field.

Recent articles have highlighted the dearth, in the academia of Bioinformatics and the need for programs that could address the sciences in the disparate fields, and immerse students in both theory and experimental aspects of Bioinformatics research to acquiring core competency in the biological and computer sciences [5-6]. These challenges have paved the way for projects for academic booming, providing opportunities and hypotheses for the introduction of experiments and applications to life through computer tools to speed up the production of massive amounts of data needed to understand the new technology [7]. Most disciplines have begun to adopt curriculum relevant to Bioinformatics and tools oriented towards information technology because of the high-performance computing, interoperability and portability of data, and compatibility on the internet [8-9].

This study reviews the Bioinformatics education in Pakistan with other countries and explains the components that constitute the Bioinformatics field, analyze the unique education criteria that are required to produce students with Bioinformatics training and provide an overview of global Bioinformatics education to further improve our implementation of Bioinformatics education.

Related Work

In the context of Pakistani perspective to develop Bioinformatics education and stepwise progress in it, Ilyas, highlights the rise of Bioinformatics in Pakistan and introduced Bioinformatics in 2003 in Pakistan [10], when Muhammad Ali Jinnah University and COMSATS Institute of Information Technology (CIIT) offered undergraduate program in this field. The Higher Education Commission (HEC) of Pakistan performs continual revision the

1. Introduction

Bioinformatics is the interdisciplinary science of using computers for the collection, processing, storage, retrieval, interpret and analyze biological data tremendous to solve biological problems; resulting from genome projects and high-throughput biological experiments. Computer systems play an important role to translate biological data into useful knowledge can be relied upon practical experiences and theories of teaching. Bioinformatics as a multidisciplinary field depend on knowledge of biology, computer science, mathematics, physics, and chemistry [1-2].

Bioinformatics focuses on two main flows of data in modern biology. The first depends on the flow of genetic information of the DNA, RNA and protein sequences, the second on the flow of information on the hypotheses [3-4]. This flow of the Bioinformatics information is considered a

curriculum in collaboration with universities. In 2006, the National Curriculum Review Committee (NCRC) defined a curriculum for the BS (4 years) and a Master degree in Bioinformatics for all public and private universities [11], and in 2010, the National Curriculum Review Committee (NCRC) of Bioinformatics revised the curriculum of Bioinformatics for BS (4-years) and MS (2-years) degree programs [12]. This initiative greatly strengthened the demand of new graduates in Pakistan, Where will be training new professionals and will be established Bioinformatics servers, which presented another market for local graduates.

While discussing on the question of a proper curriculum for Bioinformatics professional *Russ B. Altman* proposes two models [1]. The first model focuses on post-doctoral fellows having core training in a technical field of either computer science or in a sub-discipline of biology. They require specialty training in computational biology in order to become a 'computer scientist who specializes in biology' or a 'biologist who specializes in computer science'. In the second model, graduate students are trained in Bioinformatics or computational biology without a preliminary training in one of the contributing disciplines. The curriculum for these students must provide them with a set of skills which are long-lasting and endures beyond the current fads. This article argues that the idea of training undergraduates in Bioinformatics is quite intriguing. It proposes a framework for curriculum which is divided into five areas useful to the requirements of the course program in Bioinformatics. These areas include Biology, Computer Science, Statistics, Ethics and Core Bioinformatics.

Ragunath, Venkatesan & Ravimohan, designed a curriculum model to follow three tier architecture models for the Bioinformatics graduate program using a systems biology approach [13]. The three tier architecture model is based on three layers. Each layer consists of a reusable piece of code that performs specific task, each capturing a different aspect of the information as given below:

- The data layer: A front-end 'Web Server' serving static content, and potentially some cached dynamic content.
- Business layer: A middle dynamic content processing and generation level of Application server, for example ASP.net, Java, PHP platform.
- Presentation layer: A back-end Database, comprising both data sets and the Database management system that manages and provides access to the data.

And he has classified these layers into three levels: (a) Basic Subjects, (b) Intermediate Subjects and (c) Advanced Subjects.

The proposed framework involves five tracks to classify a curriculum Bioinformatics in content. As:

- 1 Hardcore Bioinformatics Track, preferred by students with Biology background.
- 2 Drug Designers Track, preferred by students with Chemistry or Biophysics background.
- 3 Analyst Track, preferred by students with a strong

background in Biostatistics and Biomathematics.

- 4 Information Technology (IT) Track, preferred by the students with IT background.
- 5 Research Track, This track is preferred by students opting for research positions.

Thus, the curriculum model which is designed for the graduate program in Bioinformatics addressed most of the issues related to the design of educational programs under each discipline to achieve these goals so that students are able to progress through their studies in an integrated manner. *Searls* identified a set of five possible tracks for Bioinformatics curriculum [7], these tracks indicated to courses in virtual departments which represent an assumed background for individuals entering the track.

- 1 Bioinformatics Analysis (BA): This track prepares students to analyze biological data in order to interpretation or prediction.
- 2 Data Mining (DM): This track provides more sophisticated analysis of data sets which are complex; it entails a greater depth of both mathematical knowledge and programming skills.
- 3 Bioinformatics Tools (BT): This track is interested to develop tools for Bioinformatics analysis, presentation, visualization, and local data management, it requires programming skills and algorithms and the ability to implement efficiently.
- 4 Bioinformatics Systems (BS): This track is one of the competencies of software engineering are able to develop main Bioinformatics systems.
- 5 Computational Biology (CB): This track aims to study and analyze complex biological data through mathematical and computational techniques of advanced.

These developments in level of Bioinformatics required many countries to develop a new model of curriculum that is taught in many universities, and which form a great challenge for most departments. Challenges and competition posed between developing countries focused on the launch of a mechanism for application of Bioinformatics in many universities through a powerful model is designed to provide quality education, and training students to use Bioinformatics tools. Here comes the important question of how to teach Bioinformatics for computational science students in the future and how to deliver the application of biology on a computer skill remains an unsolved educational riddle [14].

2. Materials and Methods

The results in this article depend on quantitative and qualitative data that collected from different sources such as websites or articles. The data has been collected based on conceptual framework (Figure 1) which considers the sample of 5 Universities for undergraduate and 5 universities for graduate level programs in Pakistan. These Universities are

listed in (Table 1&2). Similar sample of 5 universities offering undergraduate programs and 5 universities offering graduate programs was considered for 6 other developed and developing countries to ensure quantitative comparison and analysis..

Figure 1. Conceptual framework for data collection and analysis

Bioinformatics Curriculum: courses that include undergraduate and graduate program of curriculum to ensure understanding and exemplary structure to students. And strive to provide adequate learning opportunities for discovery and connectivity, creativity, and building new knowledge through the face of a problem, and seek to solve them, in order to encourage students to request information independently.

Content Area Studies: contents provide students to master the skills, ideas, concepts, values, facts and structure to their education.

Content Area Studies

To develop a new multidisciplinary field of Bioinformatics curriculum in a country like Pakistan, as elsewhere, requires the promotion and sponsorship for undergraduate and graduate programs. A Bioinformatics curriculum model is based on strong multidisciplinary field in biological, statistical, mathematical and IT/ computer

science (See Figure 2).

Figure 2. Major components of Bioinformatics curriculum

These components include most crucial subjects in Bioinformatics fields in developing curricula and address the needs of students coming from different backgrounds. Mixed composition of students showed in often to be effective, because they complement each other in the understanding of multiple disciplines and importance of Bioinformatics. Thus, Bioinformatics curriculum creates a spirit of challenge between developing countries to develop a strong framework to meet the requirements.

A comparison of various universities in developed and developing countries with selected Pakistani universities offering undergraduate and graduate degree at different levels is aimed at clarifying the importance and skills of Bioinformatics education. With variations in the course contents, this requires the introduction of amendments in current curriculum to accommodate future developments.

3. Results and Discussions

Comparison of subjects among undergraduate courses:

There are currently five universities were selected from seven countries offering Bioinformatics courses for the bachelor's degree as listed in Table 1. The curricula of the five degrees of each country were examined from the websites.

Table 1. Undergraduate Bioinformatics degrees and streams of selected countries

1. Pakistan	
Baqai Medical University	http://www.baqai.edu.pk/BiitPrograms.aspx
Mohammad Ali Jinnah University	https://www.jinnah.edu.pk/academics/course_list/of/BS+Bioinformatics
COMSATS Institute of Information Technology	http://ww3.comsats.edu.pk/CourseCatalogue2012/CourseCataloguedetails/ListofPrograms.aspx?Pid=14&Sid=2&Department=Biosciences&Session=2011-2012
Government College University	http://gcuf.edu.pk/faculties/science/bio-informatics/bs-hons-bioinformatics/
International Islamic University	http://www.iiu.edu.pk/index.php?page_id=10930
2. India	
Jaypee University of Information Technology	http://www.juit.ac.in/attachments/FinalSyllabus.pdf
Karunya University	http://www.karunya.edu.in/bioinformatics/academics/btechc.pdf
D.Y.Patil University	http://www.dypatil.in/picrepimage/DBB_Programsoffered-BioinformaticsB.Tech_Bioinformatics.pdf
SRM University	http://www.srmuniv.ac.in/sites/default/files/files/btech_syll_bie_r2013-14.pdf
Amity University	http://www.amity.edu/aib/A05042.asp
3. Australia	
Murdoch University	http://handbook.murdoch.edu.au/units/details/?unit=BIO378&year=2015
Flinders University	http://www.flinders.edu.au/courses/rules/undergrad/bsc/bsc-bion-ex.cfm
University of Wollongong	http://www.uow.edu.au/handbook/yr2005/bcompbioinf.html
University of New South Wales	http://www.engineering.unsw.edu.au/bioinformatics
University of Western Australia	http://www.studyat.uwa.edu.au/_data/assets/pdf_file/0006/2385654/study_at_uwa-2008.pdf
4. Malaysia	
Universiti Teknologi Malaysia	http://www.ukm.my/jtlhe/pdf/4%20JTLHE%2017-%20Dr%20%20Zeti%20New.pdf
Management and Science University	http://www.msu.edu.my/v9/faculty-health-life-sciences/bachelor-bioinformatics.php
INTI International University and Colleges	http://newinti.edu.my/main/academic_programmes/american-university-programme/biosciences-2
Multimedia University	http://www.campusmalaysia.com/courses/computing-it/bachelor-science-hons-bio-informatics
Universiti Selangor	http://fasbio.unisel.edu.my/bachelor-of-bioinformatics/
5. Germany	
Technical University of Munich	http://www.in.tum.de/en/for-prospective-students/bachelors-programs/bioinformatics.html
Freie Universität	http://www.mi.fu-berlin.de/en/bioinf/stud/bachelor/index.html
Saarland University	http://zbi-www.bioinf.uni-sb.de/en/information-potential-future-students/bachelors-study.html
University of Applied Sciences Mittelhessen	http://www.thm.de/site/download/doc_download/748-bioninformatik-bachelor
Bielefeld University	http://www.techfak.uni-bielefeld.de/en/bachelor-program-bioinformatics-and-genome-research-big
6. US	
Rochester Institute of Technology	http://www.rit.edu/cos/lifesciences/pdf/BioinformaticsSchedu2131.pdf
University of Pittsburgh	http://www.cs.pitt.edu/undergrad/bioinformatics/bsbi-major_req.php
University of Nebraska	http://bioinformatics.ist.unomaha.edu/docs/BIOI%20%20Packet%202009-2010.pdf
Michigan Technological University	http://www.mtu.edu/biological/undergraduate/bioinformatics/
California State University San Bernardino	http://bulletin.csusb.edu/colleges-schools-departments/natural-sciences/biology/bioinformatics-bs/
7. Canada	
University of Victoria	http://www.csc.uvic.ca/Program_Information/Undergraduate_Studies/BioinformaticsOption.htm
University of Saskatchewan	http://www.cs.usask.ca/undergrad/programs/binfo.php
University of Alberta	http://www.biology.ualberta.ca/programs/undergraduate/?Page=8508
University of Calgary	http://cumming.ucalgary.ca/bhsc/program/bioinformatics
Lakehead University	http://bioinformatics.lakeheadu.ca/undergraduate-program/

The major subjects in curriculum structure for the universities are classified into five major areas were chosen as a track for course content.

These areas were: Bioinformatics, biological sciences, IT/computer sciences, statistics and mathematics. Bioinformatics included all subjects that combined between computer science and biological science (e.g. Recombinant DNA, microarray analysis and proteomics). Computer sciences included programming subjects and other subjects. Biological sciences included all biology and chemistry subjects. Mathematics includes mathematical subjects. Statistics include all statistic and probability subjects. Each of the courses has some minor or elective subjects that fall in the other areas.

The comparison of subjects is distributed among undergraduate Bioinformatics a course within six areas is shown in (Figure 3). There were important variations in the average number of subjects representing these different countries, the subjects were selected from Bioinformatics courses which are offered by the selected universities.

Figure 3. Distribution of subject areas covered in undergraduate Bioinformatics degrees

Comparison of subjects among graduate courses: For graduate studies used the same way as used for the undergraduate studies based on selection of five universities from seven countries offering Bioinformatics courses for graduate degree are listed in (Table 2).

Table 2. Graduate Bioinformatics degrees and streams of selected countries

1. Pakistan	
Virtual university of Pakistan	http://www.vu.edu.pk/AcademicPrograms/StudyScheme.aspx?sp=MS_in_Bioinformatics
Quaid-a-Azam University	http://ncb.qau.edu.pk/index.php/programmes.html
University of the Punjab	http://pu.edu.pk/program/description/5501#
CECOS University	http://www.hec.gov.pk/insidehec/divisions/aeca/curriculumrevision/documents/bioinformatics-2010.pdf
University of Sindh	http://www.usindh.edu.pk/
2. India	
Institute of Bioinformatics and Applied Biotechnology	http://www.ibab.ac.in/wp-content/uploads/2013/12/Syllabus_MSc-programme.pdf
Pondicherry University	http://www.pondiuni.edu.in/sites/default/files/downloads/Bioinformatics2011-12-190413.pdf
Savitribai Phule Pune University	http://www.unipune.ac.in/snc/bioinformatics_centre/bioinfo_webfiles/syllabus.htm
West Bengal University of Technology	http://www.wbut.ac.in/page.php?id=255
Integral University	http://www.integraluniversity.ac.in/syllabus/MTechBioinformatics.pdf
3. Australia	
Australian National University	http://programsandcourses.anu.edu.au/2015/specialisation/QBIL-SPEC
University of Melbourne	https://graduate.science.unimelb.edu.au/master-of-science-bioinformatics
Sydney University	http://sydney.edu.au/handbooks/archive/2011/science/postgraduate/coursework/bioinformatics.shtml
University of Queensland	http://www.uq.edu.au/study/program_list.html?acad_prog=5541
La Trobe University	http://www.latrobe.edu.au/courses/feature/science-and-psychology/master-biotechnology-bioinformatics
4. Malaysia	
University of Malaya	http://www.ips.um.edu.my/?modul=Programmes_Offered&pilihan=Master_of_Bioinformatics
Universiti Putra Malaysia	http://www.hotcourses.com.my/study/course/malaysia/master-of-science-bioinformatics-and-system-biology-research/52872596/program.html
Perdana University	http://bioinfo.perdanauniversity.edu.my/pgdip/pgdip_brochure.pdf
Universiti Tunku Abdul Rahman	http://www.hotcoursesabroad.com/india/course/malaysia/master-of-science-computer-science-bio-informatics-research/55413858/program.html
AIMST University	http://www.aimst.edu.my/faculties/applied_sciences/applied_sciences.php
5. Germany	
Max Planck Gesellschaft	http://www.biochem.mpg.de/1819400/Bioinformatics-Core-Facility
Ludwig Maximilian University	http://www.uni-muenchen.de/studium/studienangebot/studiengaenge/studienfaecher/bioinform/_master/index.html
University of Giessen	http://www.uni-giessen.de/cms/study/courses/master/bioinformatics?set_language=en
University of Freiburg	http://www.tf.uni-freiburg.de/studium/studiengaenge/master/studienplaene/bioinformatik2010_semester.pdf
University of Bonn	http://www.b-it-center.de/Wob/en/view/class211_id1141.html
6. US	
Rowan University	http://rowanu.com/sites/default/files/documents/program-overviews/science-math/14-15/MS-Bioinformatics.pdf
Ohio University	http://www.ohio.edu/bioinformatics/programs.cfm
George Mason University	http://masononline.gmu.edu/programs/bioinformaticsandcomputationalbiologym/
Northeastern University	http://www.northeastern.edu/seattle/wp-content/uploads/2014/12/Bioinformatics-Slick-2014.pdf
Boston University	http://www.bu.edu/bioinformatics/admissions/programs/md-track/
7. Canada	
Simon Fraser University	http://www.sfu.ca/bioinformatics/grad/courses.html
Carleton University	http://calendar.carleton.ca/grad/gradprograms/bioinformatics/
University of Toronto	http://gbb.utoronto.ca/index.php/Category:Student_Members
University of British Columbia	http://bioinformatics.bcgsc.ca/courses/index.html
McGill University	http://www.mcgill.ca/mcb/academic/graduate

The comparison subjects are distributed among graduate Bioinformatics courses within six areas is shown in (Figure 4). The distribution based on total subjects that fall in the Bioinformatics, biological science, IT/ computer science, mathematical, statistical and elective or other subject in the course.

Figure 4. Distribution of subject areas covered in graduate Bioinformatics degrees

In this study, it is possible to make comparison through a number of various subjects that fall in major areas. This variation in the subjects means that some degrees are more skilled in producing Bioinformatics technicians.

4. Conclusions

Through this study, some of the flagship initiatives related to Bioinformatics have been investigated in various countries and compared with the state-of-the-art standards of Bioinformatics education in Pakistan. Many nations around the world have taken initiatives for proper adoption and restructuring of Bioinformatics educational frameworks.

The crucial subjects in the Bioinformatics field fall in biology, mathematical, statistical and IT/ computer science. Therefore, the selected curricula depend on institute offering Bioinformatics degree, if the computer science institute offers Bioinformatics degree most subjects selected from the computer science side, but if the biology institute offers Bioinformatics degree most subjects from biology side, and so on. Different institutes have different curricula.

The contents of the undergraduate courses have more mathematics related subjects and as well as a number of overall subjects as compared to other developed countries. On the other side, the number of overall subjects in graduate courses is significantly less as compared to international counterparts. These ratios need to be balanced during future curriculum revision initiatives. The Bioinformatics courses in Pakistan emphasize on graduate programs more than undergraduate programs.

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REFERENCES

- [1] Altman, R. B. (1998), 'A curriculum for Bioinformatics: the time is ripe', *Bioinformatics*, 14(7), 549-550.
- [2] Madhani, P. M. (2011), 'Indian Bioinformatics: Growth Opportunities and Challenges', *PRERANA, Journal of Management Thought and Practice*, 3(2), 7-17.
- [3] Altman, R. B. (1998), 'Bioinformatics in support of molecular medicine', In *Proceedings of the AMIA Symposium* (p. 53). American Medical Informatics Association.
- [4] Koch, I., & Fuellen, G. (2008), 'A review of Bioinformatics education in Germany', *Briefings in bioinformatics*, 9(3), 232-242.
- [5] Counsell, D. (2003), 'A review of Bioinformatics education in the UK', *Briefings in Bioinformatics*, 4(1), 7-21.
- [6] Zatz, M. M. (2002), 'Bioinformatics training in the USA', *Briefings in bioinformatics*, 3(4), 353-360.
- [7] Searls, D. B. (2012), 'An online Bioinformatics curriculum', *PLoS computational biology*, 8(9), e1002632.
- [8] Cummings, M. P., & Temple, G. G. (2010), 'Broader incorporation of Bioinformatics in education: opportunities and challenges', *Briefings in Bioinformatics*, 11(6), 537-543.
- [9] Richard, R. J. A., & Sriraam, N. (2005), 'A feasibility study of challenges and opportunities in computational biology: A Malaysian perspective', *American Journal of Applied Sciences*, 2(9), 1296.
- [10] Ilyas, M., Sadique, S., Masood, K., Qamar, R. and Chohan, S.N. (2011). 'The development of computational biology in Pakistan: still a long way to go', *PLoS Comput Biol*, 7(6), p.e1001135.
- [11] Higher Education Commission 2006, Islamabad, MS & BS Bioinformatics program description. Available from: <<http://www.hec.gov.pk/InsideHEC/Divisions/AECA/CurriculumRevision/Documents/Bioinformatics-2006.pdf>>. [05 July 2006].
- [12] Higher Education Commission 2010, Islamabad, MS & BS Bioinformatics program description. Available from: <<http://www.hec.gov.pk/insidehec/divisions/aeca/curriculumrevision/documents/bioinformatics-2010.pdf>>. [01 June 2010].
- [13] Ragunath, P. K., Venkatesan, P., & Ravimohan, R. (2009), 'New Curriculum Design Model for Bioinformatics Postgraduate program using Systems Biology Approach', *J Comput Sci Syst Biol*, 2, 300-305.
- [14] Pevzner, P. A. (2004), 'educating biologists in the 21st century: Bioinformatics scientists vs. Bioinformatics technicians', *Bioinformatics*.