Journal of Computer Science & Systems Biology - Open Access

JCSB/Vol.2 November-December 2009

Research Article OPEN ACCESS Freely available online doi:10.4172/jcsb.1000046

New Curriculum Design Model for Bioinformatics Postgraduate program using Systems Biology Approach

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Abstract

Bioinformatics is the application of information technology to the field of molecular biology. In formal education, a curriculum is the set of courses, and their content, offered at a school or university. Curriculum design should take into account intentions and outcomes. It should encourage students to make choices and explore their consequences. Hence, the need arises for developing a new method for curriculum development for a course in Bioinformatics (which is a truly interdisciplinary in nature). Systems Biology Approach is a biology-based inter-disciplinary study field that focuses on the systematic study of complex interactions in biological systems, thus using a new perspective (holism instead of reduction) to study them. We have evolved a new curriculum design using the System Biology Approach (SRU Model) for the M.Sc. bioinformatics course in the Department of Bioinformatics in Sri Ramachandra University, India. The curriculum is designed to follow the three tier architecture model. The results have been very encouraging and this Curriculum Design model is portable for any other courses.and the details are discussed.

Keywords: Systems biology; Curriculum design; Bioinformatics; SRU model; Three tier architecture; Syllabus; Curriculum development; Postgraduate program

Introduction

Bioinformatics

Bioinformatics is the application of information technology to the field of molecular biology. The term bioinformatics was coined by Paulien Hogeweg in 1979 for the study of informatic processes in biotic systems. Bioinformatics now entails the creation and advancement of databases, algorithms, computational and statistical techniques, and theory to solve formal and practical problems arising from the management and analysis of biological data. It is the name given to these mathematical and computing approaches used to glean understanding of biological processes.

Curriculum

In formal education, a curriculum is the set of courses, and their content, offered at a school or university. As an idea, curriculum stems from the Latin word for race course, referring to the course of deeds and experiences through which children grow to become mature adults. A curriculum is prescriptive, and is based on a more general syllabus which merely specifies what topics must be understood and to what level to achieve a particular grade or standard (Bobbitt, 1918). The education programmes under each discipline are designed to meet these objectives so that students are able to progress through their courses in an integrated manner.

Syllabus

Syllabus is an outline or other brief statement of the main points of a discourse, the subjects of a course of lectures, the contents of a curriculum, etc. It is a summary of topics which will be covered during an academic course, or a text or lecture.

Curriculum Models

The Descriptive models describe (a) Actual work of the curriculum designers and (b)Topics that are covered in the curriculum.(c)One of the more well known examples is the "objectives model," which arose from the initial work of (Tyler, 1949). According to this model, four important questions are used in curriculum design.

An enduring example of a descriptive model is the situational model advocated by (Skilbeck, 1975), which emphasises the importance of situation or context in curriculum design. The impact of both external and internal factors is assessed and the implications for the curriculum are determined. (a) Focus on the 21st century— Wilson, (1991) conducted a 3-year collaborative research project to develop curricula for the 21st century. Dominant themes included change and adaptability, global interdependence and cultural diversity, quality of life, technology, and self-actualization.(b) Holistic, multidisciplinary curricula—Several authors (Hunkins and Hammill, 1994; Relan and Kimpston, 1991) believe that curricula should be holistic, unfettered by preestablished rules, responsive to conditions of constant change and unpredictability, emergent rather than fixed, and inviting synthesis rather than fragmentation of thinking. (c) Integrated approaches to curriculum design have been associated with "intermingling" of disciplines such as thinking, reasoning, and problem-solving capabilities (Relan and Kimpston, 1991; Komski, 1990). Interdisciplinary curricula offer strong advantages and can best be prepared and delivered by designers working as teams (Martinello and Cook, 1994). (d) Strong tie to the workplace—Askov, (1992) recommends a strong tie to concerns of the workplace to hold the attention of adult learners. At the same time, however, curricu-

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Received November 26, 2009; **Accepted** December 24, 2009; **Published** December 24, 2009

Citation: Ragunath PK, 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. doi:10.4172/jcsb.1000046

lum development should incorporate learning strategies and thinking processes, not merely "content" (Meyers et al., 1991). (e) Focus on outcomes—Curriculum design should take into account intentions and outcomes. It should encourage students to make choices and explore their consequences (Coleman, 1991). (f) Valuing of cultural diversity—Intercultural communication courses are necessary for teachers at every level. Multiculturalism and cultural diversity will have immense impact on global society, and multicultural issues should be incorporated into traditional curricula (Sessoms, 1994).

The advantages of these models are (a) Thinking (b) Reasoning. (c) Problem Solving. The disadvantages of these models are (a) Change and adaptability is required for the course. (b) Global interdependence and cultural diversity needs to be considered. (c) Quality of life (standard of living of the country/region), technology (facilities that can be provided to the students of the country/religion). (d) Holistic approach is necessary. (e) It should be unfettered by preestablished rules. (g) Responsive to conditions of constant change and unpredictability needs to be considered. (h) It should be evolving, rather than fixed. (i) Thinking processes need to be identified for the course. (j) Student's intentions on what they want from the course should be considered.(k) Student outcomes need to be quantified and measured-How many students have been successfully placed is a measure of the effectiveness of the course. (l) Multicultural issues need to be considered.

Each of these models for curriculum development does not take into consideration all the factors that are required for curriculum development together. The existing methods cannot be applied directly for the curriculum development of a course in Bio Informatics. Hence, the need arises for developing a new method for curriculum development for a course in Bioinformatics (which is a truly interdisciplinary in nature).

In the SRU Model we have used the System Biology Approach in Curriculum Development.

Input

The candidates passing out of this course can specialize in their respective domains in graduation viz., IT, ITES, Biomedical, Science or Management or specialise in Bioinformatics. The choice is left to them and the curriculum is so designed to include subjects from these various domains. **Pls Refer Supplementary 2**

A systematic approach has been followed where we have ensured that the curriculum moves from simple subjects to the most complicated ones. This approach has been followed for all the subjects to ensure quality and a graded approach where the student does not feel that the subject taught is too difficult to learn.

The Systems approach to course and curriculum design is no more than an attempt to use a process of logical development and on-going monitoring and evaluation in order to allow a continuous evaluation of the course or curriculum to take place (Romiszowski, 1988).

The Systems approach can be used at any time when a episode of teaching/learning of any length is being planned. It can be applied to long term planning for a whole course lasting weeks, months or years. Through daily lesson planning, or even on the spot planning for learning experience of only a few seconds duration (Gagne, 1987). A number of writers have presented much more sophisticated systems, but these are considered to be unnecessarily complicated for our present purposes (Romiszowski, 1984).

Material

The SRU model (new model) has been implemented in the Department of Bioinformatics, Sri Ramachandra University, India for M.Sc Bioinformatics program for 5 batches. **Pls Refer Supplementary 2**

Methods

System biology Approach (Evolving Model)

One of the theorists who can be seen as a precursor of systems biology is Ludwig von Bertalanffy with his general systems theory, and his book titled "General Systems Theory in Physics and Biology" was published in 1950. One of the first numerical simulations in biology was published in 1952 by the British neurophysiologists and Nobel Prize winners Alan Lloyd Hodgkin and Andrew Fielding Huxley, who constructed a mathematical model that explained the action potential propagating along the axon of a neuronal cell (Hodgkin and Huxley, 1952). Their model described a cellular function emerging from the interaction between two different molecular components, potassium and a sodium channels, and can therefore be seen as the beginning of computational systems biology (Systems Biology). In 1960, Denis Noble developed the first computer model of the heart pacemaker (Mesarovic, 1968). The formal study of systems biology, as a distinct discipline, was launched by systems theorist Mihajlo Mesarovic in 1966 with an international symposium at the Case Institute of Technology in Cleveland, Ohio entitled "Systems Theory and Biology" (Means, 1992; http://www.davislearn.com). Systems Biology Approach is a biology-based inter-disciplinary study field that focuses on the systematic study of complex interactions in biological systems, thus using a new perspective (holism instead of reduction) to study them. Particularly from year 2000 onwards, the term is used widely in the biosciences, and in a variety of contexts. Because the scientific method has been used primarily toward reductionism, one of the goals of systems biology is to discover new emergent properties that may arise from the systemic view used by this discipline in order to understand better the entirety of processes that happens in a biological system.

Still other sources view systems biology approach in terms of the operational protocols used for performing research, namely a cycle composed of theory, analytic or computational modelling to propose specific testable hypotheses about a biological system, experimental validation, and then using the newly acquired quantitative description of cells or cell processes to refine the computational model or theory (Kholodenko et al., 2005; Systems Biology - the 21st Century Science). Since the objective of this model is of the interactions in a system, the experimental techniques that most suit systems biology approach are those that are system-wide and attempt to be as complete as possible.

In the SRU model for the curriculum development, we have used the System Biology Approach for the M.Sc. bioinformatics course in the Department of Bioinformatics in Sri Ramachandra University. It incorporates the following points.

a) Flow approach has been followed in the curriculum design.
b) Three-tier architecture has been followed in the curriculum design.
c) The curriculum is easy to implement.
d) In the curriculum we move from the basic subjects to the advanced ones.
e) Staff structuring can be easily done.
f) Learning content describes the subjects in the curriculum.
g) There is layering of subjects in the curriculum.
h) Input is in the form of undergraduate courses in various domains.
i) Output is in the form of post graduate students in bioinformatics.
j) A systematic approach has been followed.
k) Bridge courses are used to bring down the knowledge gap of students.
l) Lab design is easy to implement.
m)There is a lot of flexibility in the staffing pattern.
n) Placement of past students has been considered.
o) In respect of Staff training and recruitment a lot of flexibility is there.
p) New developments can be very easily incorporated in the curriculum.
q) The curriculum is highly flexible.
r) We have followed the template approach to develop the curriculum.
s) This curriculum can be upgraded very easily.
t) Portability of this curriculum for any other course is also possible.

Flow design

The curriculum has been so developed to ensure a flow design where each of the subjects flows from the previous one. Effort has been made to ensure that the curriculum moves from the simple subjects to the most complicated ones. Ideally, students find their assignments both challenging and engaging. Psychologist Mihaly Csíkszentmihályi calls this optimal experience of positive engagement "flow." A student experiencing flow is intrinsically motivated, finding enjoyment and reward in the performance of the task itself (Csikszentmihalyi, 1995). As in Stephen Covey's motivational book Seven Habits of Highly Effective People, the seven characteristics presented here have been part of the common experiences of creative and successful people throughout history (Stephen Covey's motivational book Seven Habits of Highly Effective People).

Course Input

The students joining this post graduate course in bioinformatics can be from various domains. They can be from IT, or ITES, or Biomedical, Science or management domains. In spite of coming from various domains they still will have some subjects relating to these domains in the curriculum. Hence the students will be very comfortable when these subjects relating to their domains are taught and they can specialise in any one of them or any other bioinformatics subject. The input to a given teaching/learning system consists of people, resources and information, the output consists of people whose performance or ideas (it is to be hoped) improved in some desired way.

Boris proposed allowing students to advocate topics for courses and to help plan course objectives (Castro, 1991). Castro has published some techniques that shift the classroom experience from instructor-centered to student-centered (Castro, 1991). Feaster found benefits to collaborative learning (Feaster, 1992), and Fox and Harvey encouraged giving students responsibility for planning their own individual courses of studies (Fox and Harvey, 1993).

Bridge Courses

The bridge courses are designed for students as they have not studied these subjects in the domain from where they come from. Once they undergo this bridge courses they will become on par with the other students. Their comfort levels will also increase once they have learnt the subject and they will not feel left out. The bridge courses are meant to teach graduate level material. These bridge courses were useful to the students without strong back ground in Biology or Mathematics.

Currently about a third of all entrants to the Post graduate Course in Bioinformatics join the course without having gone through an B.Sc. course in Chemistry, BioPhysics, Biology, BioStatistics, Biomathematics. Such students often have high levels of skill, but lack some of the background knowledge that the other students have. The bridge courses are being designed to overcome the consequent practical problems by filling the information gap between the average M.Sc. course in India and the others (Tata Institute of Fundamental Research (TIFR) 2nd May 2005).

Layering of Subjects

The suggested framework implies a layered information structure of the content consisting of three layers, each capturing a different aspect of the information space—conceptual, resource-related, and contextual. Conceptualization can support topical finding of resources and learner's understanding of the specific subject domain (by enabling exploration of related domain concepts). Subject domain conceptualization has been long used for knowledge representation in intelligent tutoring systems (ITS). More recently, concept structures play a central role in adaptive hypermedia (AH) applications—for content fragmentation and structuring, and in a concept-based course (Eklund et al., 1997).

Track 1

This track is known as Hardcore Bioinformatics track, preferred by students with Biology background and were able get the job in Bioinformatics companies.

Track 2

This track is known as "Drug Designers" track. This is preferred by students with Chemistry or Biophysics. The students were able get the placement in Pharmaceutical companies.

Track 3

This track is known as "Analyst Track' and preferred by students with strong background in Biostatics and Biomathemat-

ics. They have got placed in Bioinformatics companies where high end analysis is being used. Apart from that they were able to get jobs in companies as Business Analysts.

Track 4

This track is known as "IT" track and preferred by the students with IT background. They were able get jobs in various IT companies.

Track 5 (optional)

This track is also known as "Research Track". This track was useful to the students who have opted for research positions. **Pls refer Supplementary 5 flow chart**

Three tier architecture

In three tier system architecture model there are three layers. A layer is a reusable portion of code that performs a specific function. The data layer, business layer and finally the presentation layer.

First layer: A front end Web server serving static content, and potentially some cached dynamic content. Second layer: A middle dynamic content processing and generation level Application server, for example Java EE, ASP.net, PHP platform. Third layer: A back end Database, comprising both data sets and the Database management system or RDBMS software that manages and provides access to the data (Eckerson, 1995). The advantages of three tier architecture are (a) usability, (b) flexibility, (c) interoperability, and (d) scalability. The three-tier Web application architecture offers the following advantages: (a) High performance, lightweight persistent objects (b)High degree of flexibility in deployment platform and configuration (Ariel Ortiz Ramirez Three-Tier Architecture in Linux Journal).

The advantages of three tier architecture are (a) Scalability (b) Better Re-use (c) Improved Data Integrity. (d) Improved Security. (e) Reduced Distribution. (f) Improved Availability (g) Hidden Database Structure (Oracle Top Link Developer's Guide 10g Release 3 (10.1.3)).

The curriculum is designed to follow the three tier architecture model. In three tier architecture there are 3 layers. With regards to the subjects we have classified them into three levels.

(a) Basic Subjects
(b) Intermediate Subjects and
(c) Advanced Subjects.

This is how we have applied the three tier architecture to our subjects.

Student placement

The candidates passing out of this course can specialize in their respective domains in graduation viz., IT, ITES, Biomedical, Science or Management or specialise in Bioinformatics. The choice is left to them and the curriculum is so designed to include subjects from these various domains. **Pls Refer Supplementary 1**

Easy to design- Lab

The labs have been designed to follow the three tier architecture. Students are taught the various operating systems like Windows and Linux. Then they are taught languages and programming. Finally they are taught how they can use the freewares in bioinformatics. Hence they have 3 different labs.

One lab is exclusively for freeware in bioinformatics which are available free over the internet. The second lab is for using commercial software in bio informatics which is quite expensive. The third lab is called the skills lab. The idea behind this is that the students will study the freeware and commercial software and design new software in the skills lab. Hence the students can develop their own software after identifying the problems in both freeware and commercial software. **Pls Refer Supplementary 3**

Staffing pattern – flexibility

A suitable staffing pattern has been identified according to the subjects in the curriculum for MSc Bioinformatics course. **Pls refer Supplementary 4**

Discussions

The reductionist approach has successfully identified most of the components and many of the interactions but, unfortunately, offers no convincing concepts or methods to understand how system properties emerge...the pluralism of causes and effects in biological networks is better addressed by observing, through quantitative measures, multiple components simultaneously and by rigorous data integration with mathematical models" (Le, 2007). (a)Change and adaptability is required for the course. (b)Global interdependence and cultural diversity needs to be considered. (c)Quality of life (standard of living of the country/region), technology (facilities that can be provided to the students of the country/religion)(d)Holistic approach is necessary.

The SRU model of curriculum is very easy to implement because it basically follows the 3 tier architecture. So we have to classify the subjects as basic, intermediate and advanced. Then based on this, the basic subjects will be taught first, then the intermediate subjects and finally the advanced ones. This is done to ensure that students who come from various domains like IT, ITES, biomedical, science and management do not feel out of place in this course.

What I liked most was how easily these strategies fit into many areas of curriculum.

The SRU model of curriculum is very easy to implement because it basically follows the 3 tier architecture. So we have to classify the subjects as basic, intermediate and advanced. Then based on this, the basic subjects will be taught first, then the intermediate subjects and finally the advanced ones. The students will be moving from the basic ones to the intermediate and then to the advanced ones. Hence the students will not feel out of place and feel that they are studying a difficult subject as their comfort level is not disturbed. The system biology approach states that we should not follow the reductionist approach (Snoep et al., 2005). Instead we should find out how the individual components interact with each other and integrate as one whole object (A Means Toward a New Holism). The importance of each one of these individual components should not be undermined at any cost,as the sum of these indi-

vidual components interacting as one whole unit leads to success of this system biology approach (Noble, 1960).

Easy to design- Lab

We found the lab design structure evolved for SRU model is very easy to implement. **Pls Refer Supplementary 3**

Staffing pattern – flexibility

A suitable staffing pattern has been identified according to the subjects in the curriculum for M.Sc Bioinformatics course. We have applied to the SRU model for 5 batches of students for the course M.Sc in Bioinformatics for a period of 5 years. "Life inside college and outside it, there is nothing in common. The outside world's jobs, issues, problems are so different. In short, the curriculum should cover life outside the college and university campuses" (Sharma, 2007).

Staff recruitment and training

We have applied to the SRU model for 5 batches of students for the course M.Sc in Bioinformatics for a period of 5 years .In the SRU model, we can add any new discoveries can easily be incorporated into this curriculum as the basic structure is so designed to promote further inclusion at a later date. As the curriculum evolves over a period of time, new developments can be incorporated.

Flexibility

In this model addition and deletion to this curriculum is possible as its basic design allows this flexibility. So whenever a new development happens it can be added very easily to this curriculum. Whenever a subject becomes obsolete it can be removed and substituted with a new subject.

Template

As we have used the template method we can use it for further new developments in curriculum development.

Upgradation

Upgradation of this curriculum is very easy as addition and deletion is possible without affecting the regular flow of the subjects.

Portability

By following the 3 tier architecture model we have ensured that the portability of the curriculum can be ensured whenever changes are made and new developments need to be incorporated in the curriculum. This SRU model can be applied to the curriculum design of courses in Engineering, Medical and Science Domains.

Reusability

This model of curriculum development can be reused for any other course as the model is ideally suited to adapt itself for other courses. We have applied to the SRU model for 5 batches of students for the course M.Sc in Bioinformatics for a period of 5 years.

Quality

This model of curriculum design ensures that quality can be maintained at any level.

The Department of Bioinformatics has been certified ISO 9001:2000. The SRU model allows the principles of quality mangament to be applied in the design of the curriculum to suit their requirements.

Student placement

The results have been very encouraging and they have been able to maintain high placement record for all these 5 batches. **Pls Refer Supplementary 1**

Conclusion

Thus the SRU model which we have evolved for the post graduate program in Bioinformatics addresses most of the issues related to curriculum design as it uses the System Biology Approach.

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