Bioinformatics Knowledge Transmission (training, learning, and teaching): overview and flexible comparison of computer based training approaches.

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Abstract: The merger of computer science, mathematics, and life sciences has brought about the discipline known as bioinformatics. However, the transmission (e.g. training, learning, and teaching) of this knowledge becomes an important issue. Many tools have been developed to help the bioinformatics community with that transmission challenge. When selecting the best of these tools, called here BKTMS (Bioinformatics Knowledge Transmission Management Systems), there may be confusion. What makes a good BKTMS? How can we make this choice efficiently? These questions remain unanswered for many users (e.g. learner, teacher and student, trainer and trainee, administrator). This paper provides a critical review of 32 existing BKTMS and a flexible comparison. This review and evaluation will be used to gain insight into the tools, systems, and capabilities that will be added to or excluded from a new proposed model for the next generation of BKTMS, involving multidisciplinary, web semantic tools (e.g. web services, workflow) and standards like LOM, or SCORM.

Keywords: bioinformatics, learning object, knowledge transmission, education, multidisciplinary.

Introduction

Bioinformatics allowed creation of vast knowledge amounts based on data, tools, processes, and technology. Bioinformatics aims to use and create technologies for identification, manipulation, modification, and creation of life science data. Currently, the transmission of bioinformatics knowledge and skills is a difficult task to accomplish [1]. The growing mass of bioinformatics knowledge, data, and tools has led to a growing need for adequate knowledge transmission and collaborative tools.

The diversity of academic domains, student profiles, and skills requires the specialization and the personalization of bioinformatics training programs. Over the past ten years, higher education institutions have begun to offer courses in bioinformatics and computational biology [2]. A survey conducted by Messersmith et al. shows that about 30% of United States universities offered bioinformatics educational workshops as of 2011 [3]. Some high schools in the world have begun education in bioinformatics as well [4]. In addition, we are witnessing a growing development of tools for managing the transmission of knowledge using computer engineering, called computer-based training (CBT). Users are faced with the difficulties of choice and the good definition quality of the results. In the bioinformatics field, the complexities of the subjects (i.e. multidisciplinarity) and the diversity of training needs make a choice even more difficult. Indeed, most of the management tools for bioinformatics knowledge transmission that have been developed in recent years are related to proprietary needs or specific bioinformatics software (e.g. ExPASy, EBI, NCBI, ...). Other management tools try to adapt existing educational frameworks to facilitate standardization of their content (e.g. E-Biomics, EMBR, OpenHelix, etc.). Others tried to build new transmission strategies based on Bioinformatics knowledge networking (e.g. BTN, Biostar). However, it is difficult to select the appropriate
BKTMS from this panoply of BKTMS. An evaluation of these tools proves necessary.

For example, possessing statistics skills can qualify a person for several career profiles such as systems biology modeling, data analysis, or data modeling (data learning). This concept of knowledge transmission requires modularity of transmitted knowledge. In fact, to transmit the knowledge necessary for understanding complex concepts in bioinformatics and computational biology such as modeling of systems biology [5], [6], a BKTMS needs modularity to facilitate both transmitting and receiving. Standardization, modularity, reusability and flexibility prove to be important in the design criteria of BKTMS (Yusof, Mansur, & Othman, 2011; [8]). This paper presents a critique of 32 existing BKTMS and a flexible score-based comparison of these BKTMS with 8 generic Learning Management System (LMS).

1. Bioinformatics Knowledge Transmission Management System (BKTMS) overview

A BKTMS is a web portal that provides resources for learning, teaching, training, or helping with executing bioinformatics work/problems. It can be a learning object repository (LOR), learning management system (LMS), courses management system (CMS), virtual learning environment (VLE), computer based training (CBT) portal or a simple website. These portals intend to offer a service to different groups of users in order to facilitate an understanding of specific tools, databases, functions, exercises, bioinformatics processes, programs, skills, and career profile requirements. In many cases, this service is made available for educational purposes in order to advance knowledge and understanding in bioinformatics.

There are some existing portals. What are their flaws and benefits? Table 1 indicates a number of portals reviewed with a standard set of theoretical parameters. Some descriptive parameters and information can be found in the educational tools evaluation system literature (Landon, Henderson, & Poulin, 2006, [2]. Our selected features to describe tools are: tool identification (Portal name, Base Institution, contact/author, main Statement/Goals, URL/location, comments) and technical information (approach, login, freely downloadable accessible materials, updates clearly indicated, reviewing/ranking material option, searchable materials, trainer/contact information, information about training facilities, links to courses and events).

Using these features, Table 1 describes 32 BKTMS. With some BKTMS there was no clear approach in the design or learning strategy, but instead a presentation collection of training resources. Through the accessibility evaluation criteria, BKTMS are categorized as free, partially free (free for academic use for example), and paid systems. Free tools are preponderant. To the nature and organization of content, there is a low diversity of formats (usually slides, videos or text). The organization is usually related to owner activities. BKTMS are usually organized by topics, by subdomain, by tool (software, database), on application or case study (DNA sequence analysis). This organization diversity attests to the complexity of the bioinformatics domain, but reveals that standardization of the learning context should be evaluated for efficient bioinformatics knowledge transfer.

Many of the tools and portal aspects mentioned previously are required for a competent bioinformatics training portal; however, a few new integrations would be useful as well. Many portals include profiles and sign-in capabilities, but it seems that none use that function as effectively as they could. A portal that allows users to sign-in to a profile, and customize that profile, could be a useful resource. A function should be implemented that allows users to build and edit workflows or training lists and save them for future use. This would drastically increase the teaching utility of the bioinformatics portal. Users need to be able to communicate with one another, form groups, and share training lists with those groups. An educator could compose a list of training materials and share that list with a group of students. This would also be a useful resource when presenting bioinformatics workshops. An application that can assess a user’s intention, skill level, and needs would be a beneficial application as well. A user could sign-in, take an assessment, and have a generated list of training materials available to complete their desired intentions. For example, consider a user who wants to learn to perform a sequence alignment. Their assessment would indicate this need and generate a list of resources including
“Introduction to BioExtract Server,” “ClustalW Usage,” and “Phylogenetic Tree Creation Tutorial” for example. Since the content is aimed at the user, a rating system for content based on user background would be advisable. Suggested categories of rating could be: high school student, post-secondary student, educator, and researcher.

Table 1 allows us to understand the BKTMS tools diversity. The diversity is based on Bioinformatics sub-domains and Bioinformatics applications. This shows that evaluation criteria for managing knowledge transmission are not yet a priority in BKTMS tools. Indeed, these BKTMS lack the factors necessary for the establishment of a complete pedagogical method. We can cite the factors as course level, monitoring and evaluation of the receiver (e.g. trainee, student), and many others. We propose a more formal study of these criteria to contribute to the improvement of the next generations of BKTMS tools.

2. BKTMS Tools comparison

a) Comparison principle

We use criteria provide in [10] because of its pluridisciplinarity and flexibility (Figure1). We provide a comparison of our review BKTMS (Table 1). That comparison involves 8 other LMS from EduTools and is described in [11].

Based on this information and our exploration of these tools, a grade table was proposed with KTMS in the rows and criteria in the columns (Table 2). Each criterion was weighted based on its importance related to the BKTMS. Based on the calculated scores, the user can select appropriate tools or use radar or histogram chart visualization for more details. The graphic visualization provides a snapshot of each KTMS position for each criterion (Figure 1 and Figure 2).

For simplification and compliance needs, grades for all criteria are brought to a discrete evaluation scale [1...8]. The numeric value of the evaluation may be changed, but with greatly improved ability to compare tools. The comparison is based on our context and our need. Each user can specify the priorities and degrees of importance to each criterion function in its own context. That is to say each criterion may have a score of 1 to 8, and a weight to express its importance in the given context.

b) Score calculation and comparison result visualization

Scores were calculated using the simple expert’s (decision maker’s) additive utility function [12] (Eq.5)

\[ f(X) = \sum_{i=1}^{m} p_i f_i(X) \]  

where \( f_i(X) = \{1,2,3,...,8\} \) is the rating grade of the criterion \( i \) for each examined alternative BKTMS \( X_j \), \( m \) is the number of criteria, and \( p_i \) is the weighted weight of a given criterion \( i \) (weight i on the total weight).

c) Grades, score calculation and score visualization.

Table 2 shows our BKTMS evaluation grades and scores. The first line contains the BKTMS name; lines 2 to 39 contain the KTMS grades for each criterion. The last line contains the score of each BKTMS weighting with the equation (Eq.5) formula. This table includes: grade for global criteria (white background) and detailed criteria (grey background), calculated score (black background) using equation (Eq.5), for global criteria (penultimate line) and detail criteria (last line). The first and second column contains the criterion name and its code, the third column contains the weight of the related criterion in our context. The remains columns contain the data related to each BKTMS. A high weight is put on pluridisciplinarity, collaboration, and networking criteria, given their predominance in bioinformatics.

Figure 2 shows radar chart visualization of KTMS global criteria scores (G) and detail criteria for each global criterion for more information: technical (T), pedagogy (P), interdisciplinary (I), communication (C), others (O) (related to Table 2).

Conclusion

How can one choose an appropriate BKTMS? What BKTMS should be used for what goals? What training? What learning? What level? What is a bioinformatics program? We can continue the list indefinitely. Depending on one’s involvement in the pluridisciplinary education world like bioinformatics, researcher can be looking for answers to some of these questions. This paper proposes some elements that can help in finding answers.
This study has primarily focused on providing a standardized critique of the existing BKTMS critics review. Even if the tools list was not exhaustive, it allowed us to present evidence of the strengths and failures of existing tools for bioinformatics knowledge transmission. Evaluation criteria were finally applied on the described BKTMS selected list.

Figure analysis has shown that the existing BKTMS has a relatively low score compared to the 8 selected LMS. And yet these BKTMS have high grades in multidisciplinary criteria. Through careful observation we noted that the grades for collaborativity, networking, and sharing criteria were low. Even strong weighting of the interdisciplinarity criteria could not compensate for this weakness.

This review and evaluation will be used to gain insight into the tools, systems, and capabilities that will be added to or excluded from a new proposed model for the next generation of BKTMS, involving web services and standards like SCORM, LOM, or IMS.

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Terminologies:
LOs: Learning Objects
LORs: Learning Object Repository
CBT: Computer Based Training
LMS: Learning Management System
KTMS: Knowledge Transmission Management System
BKTMS: Bioinformatics Knowledge Transmission Management System
SCORM: Sharable Content Object Reference Model
VLEs: Virtual learning environments
CBTE: competence-based teaching education,
HBTE: humanistic-based teacher education,
IMS: instructional management system
LOM: learning object model

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List of figures

Figure 1: Score visualization histogram for BKTMS based on global evaluation criteria T,P,I,C,O (black), and detailed criteria (grey).

Figure 2: Score radar visualization of BKTMS based on global criteria (G). Zoom on detail criteria for each global criterion for more detail, technical (T), pedagogy (P), interdisciplinary (I), communication (C), others (O) (Table 4).
| Domain of Bioinformatics | Organization/Institution | Activities | URL | Details |
|-------------------------|--------------------------|------------|-----|---------|
| Bioinformatics Organisations | - | The Bioinformatics Organisations develop computational resources to facilitate world wide collaborative research and communications between people of all educational and professional levels. It provides and promotes access to the materials and methods required, and delivers tools, research, development and education. | http://www.bioinformatics.org | - |
| Cosmology | - | - | - | - |
| EarthHistory | - | - | - | - |
| ColumbiaCollab | - | - | - | - |
| MyBio | - | - | - | - |
| e-persons | SRB | Bioinformatics learning portal for biometrics | http://www.epersons.org | - |
| SIB | - | - | - | - |
| Science and Technology | - | - | - | - |
| Galaxy | - | - | - | - |
| e-learning | - | - | - | - |
| Bioinformatics Resource Portal | - | - | - | - |
| European Bioinformatics Institute | - | - | - | - |
| National Centre for Biotechnology Information | - | - | - | - |
| Bioinformatics Online | - | - | - | - |
| Bioinformatics Training Network | - | - | - | - |
| Online Integrated Services (BIIS) | - | - | - | - |
| Bioportal | - | - | - | - |
| Bioinformatics Workshops | - | - | - | - |
| OpenEdu | - | - | - | - |
| EMBL | - | - | - | - |
| The Bioinformatics Training Resource | - | - | - | - |
| Bioinformatics | - | - | - | - |
| Virtual Academy of Bioinformatics | - | - | - | - |
| Collaboration effort | - | - | - | - |
| DNA Learning Center | - | - | - | - |
| Criteria | Table 2: BKTMS table for evaluation grades and scores calculation. |
|----------|------------------------------------------------------------------|
| Overall architecture and implementation | 6 |
| Interoperability | 5 |
| Internationalization and localization | 5 |
| Accessibility | 4 |
| Adaptability | 4 |
| Flexibility | 4 |
| Extensibility | 4 |
| Availability | 4 |
| Adaptivity | 4 |
| Collaborativity | 4 |
| LO interoperability | 4 |
| LO contextualization | 4 |
| LO Diversity | 4 |
| LO Accessibility | 4 |
| LO architecture | 4 |
| LO Design and usability | 4 |
| LO Interactivity | 4 |
| LO Verification ability | 4 |
| LO tagging ability | 4 |
| LO Retrievability | 4 |
| LO Discipline dependence | 4 |
| Total Criteria | 4 |
| Quality of pedagogical approach | 4 |
| Flexibility in pedagogical approach | 4 |
| Pedagogical criteria | 4 |
| Pluridisciplinarity cognitive map creation | 4 |
| Pluridisciplinarity learning language | 4 |
| Dominate ide definition | 4 |
| Pluridisciplinarity criteria | 4 |
| Diffusion canal quality | 4 |
| Information sources quality | 4 |
| Canal capacity | 4 |
| Communication criteria | 4 |
| Online Gradebook | 4 |
| Student Tracking | 4 |
| Real-time Chat | 4 |
| Automated Testing Management | 4 |
| Self-assessment | 4 |
| Other Criteria | 4 |
| SCORE GLOBAL CRITERIA | 10 |
| SCORE DETAILS CRITERIA | 57 |