The New Biology—Information-driven Science

Bioinformatics is an emerging sub-discipline of biology which specialises in the analysis, management and mining of biological data to accelerate and expand the practice of biological research. Due to the discipline’s multi-disciplinary and computer-intensive nature, conventional pedagogical methods for bioinformatics education have to be revised and novel pedagogical strategies adopted and customised to suit the teaching and learning needs of the field (Saravanan & Shanmughavel, 2007). In this context, e-learning tools, coupled with problem-based learning strategies, are particularly advantageous and convenient in delivering instant, hands-on practical learning experiences.

Problem-based Learning Approaches

Problem-based learning (PBL) is particularly suited for problem-based learning (PBL) due to its emphasis on independent, self-directed learning and the shift in the focus of the learning experience from teachers to the students. PBL, first introduced by McMaster University’s medical school in 1969, is an innovative collaborative teaching and learning instructional strategy in which students collaboratively solve problems under the guidance and support of facilitators (McLoughlin & Darvill, 2007; Khoo, 2003). A typical PBL learning cycle involves the introduction of a problem scenario, small group discussions with an appointed leader and scribe to generate potential solutions and the critical evaluation of these solutions. The learning process promotes active participation, problem-solving, critical thinking and self-directed learning among learners, thus transforming the traditional learning experience from teacher-directed instruction to student-centred learning, offering students a new source of empowerment (Gwee, 2009).

To harness the potential advantages these modern pedagogy methods offer, we applied and implemented several e-learning technologies to complement the PBL strategy we adopted to teach two undergraduate bioinformatics classes that are part of the integrated life sciences degree course offered at NUS.

Selecting Suitable e-Learning Technologies

As part of our educational strategy of introducing the new information-driven Biology and Bioinformatics syllabi, we adopted the PBL approach and utilised several e-learning tools to engage our students, tapping on their affinity towards technology.

The first step we took in implementing e-learning technology in the classroom was to select and introduce the appropriate software to the students. A variety of e-learning software to support PBL was introduced to Year Two (LSM2104/LSM2241) and Year Three (LSM3241) bioinformatics and biocomputing classes at NUS. Originally, these e-learning software were assembled as disparate sets of tools without any integration; some were off-the-shelf programmes, while others were developed by our in-house bioinformatics team. In this exercise, we focused on introducing four main technologies which we have had substantial positive experience in an integrated pedagogical context over the past decade.

1. BioSLAX

BioSLAX is a live CD/DVD/USB/Virtual Machine (VM) operating system (OS) created by our team at the Dept of Biochemistry’s Bioinformatics Centre (http://www.bioslax.com). We derived BioSLAX from our earliest bioinformatics versions of the Knoppix OS, called APBioKnoppix, which we adapted in the early 2000s, to facilitate bioinformatics software usage.
Since 2005, BioSLAX has been tested for teaching and training by several educational institutes (Figure 1). The latest version (v7.5 2009) is a portable and scalable system fully equipped with LAMP (Linux-Apache-MySQL-PHP/PERL), Mediawiki and more than 200 freely available bioinformatics software. BioSLAX is completely modular and new packages, patches or fixes can be inserted easily by creating modules which developers can add to an existing BioSLAX system. Bootable from any PC, BioSLAX runs the compressed Slackware flavour of the Linux OS (i.e. SLAX). The system is isolated from and independent of the OS installed in the user’s computer. As such, changes to the BioSLAX OS can be saved and loaded on the next start up.

**Ease of Accessibility Facilitates Practice**

We used various methods to distribute BioSLAX in our classes, including via the Web (http), File Transfer (ftp), distribution of physical CD/DVD/USB drives and more recently, through cloud computing servers such as our in-house Citrix Xen Cloud server. In future, we may distribute BioSLAX through commercial cloud servers such as GoGrid Cloud Hosting (http://www.gogrid.com) or Amazon Web Services (http://aws.amazon.com). Students are encouraged to acquire hands-on experience using bioinformatics software in an independent, customisable manner. Since BioSLAX is a LiveOS, students can load their own copies of the BioSLAX OS onto the class computers or their personal computers at home without fear of affecting the configurations of these machines. As such, students can immediately practise all the techniques that they have been taught in these modules. Furthermore, BioSLAX serves as the central point of access to other e-learning tools we introduced to the classes, as described in the next few pages.

2. **Learning Activity Management System (LAMS)**

To facilitate the mastery of various BioSLAX applications and to support PBL, we successfully deployed the Learning Activity Management System (LAMS). This is a revolutionary web-based tool, developed by the Macquarie E-Learning Centre for Excellence (MELCOE) in Australia, for managing and delivering online collaborative learning activities that can be linked together to form an intuitive learning sequence (Figure 2). With LAMS, instructors are able to monitor their students’ progress in real-time, allowing for efficient, timely assessment and feedback. Students are free to learn at their own pace and interact with their peers as well as instructors, which is in line with our objectives of fostering independent as well as collaborative teaching and learning. Facilitators can also modify the learning sequence mid-term if they need to adjust the content and pace to suit the needs of particular students. For example, instructors can get weaker students who fail to grasp certain concepts to work on additional exercises, while those who can grasp these concepts can proceed without being held back.

Figure 2. The LAMS learner interface. In this example, we see how the task list tool is used to present the learning issues for a particular PBL session. Students can add a comment and discuss each issue online with their classmates.
LAMS has been used for the asynchronous delivery of teaching and learning content in our bioinformatics classes and is currently hosted on a 32-bit Windows 2008 cloud server that can be accessed at our website (http://biocloud.bic.nus.edu.sg). We found LAMS to be particularly useful for explaining a sequence of actions to students, such as the usage of bioinformatics software in BioSLAX.

3. Wiki

As the third key component of our e-learning system, we selected Wiki technology which students could use to share what they have learnt on the BioSLAX platform as guided by the LAMS sequences. The wiki pages enable students to communicate and share their results online with each other. Also, their collaboratively written weekly reports can now be conveniently evaluated through a paperless interface. With the wiki interface, students as well as their tutors can directly edit documents and sub-blocks of documents simultaneously. This fosters collaborative authoring of the progress and learning reports (Figure 3) and helps students reflect on what they have learnt by crystallising their knowledge and thoughts into words.

Figure 3. An example of a wiki page interface created by a group of LSM3241 students on the MediaWiki site.

A key advantage of the wiki technology lies in its gentle learning curve and the ease with which pages can be created and edited (Ciesielka, 2008; Kardong-Edgren et al, 2009). MediaWiki 1.5.5, a free software wiki package written in PHP script, is currently installed in our teaching computer server, which is equipped with an Intel Pentium 4 3.0 GHz central processing unit (CPU) and 1 GB of random-access memory (RAM) to support at least 100 concurrent users (see our MediaWiki site at http://everest.bic.nus.edu.sg/mediawiki/index.php). As a back-up, students occasionally use online programmes such as Google Docs (http://docs.google.com/) and Dropbox (http://www.dropbox.com/). After grading has been completed, all wiki pages, PowerPoint presentations and final report documents are eventually uploaded to our course wiki. These archived documents allow future batches of students to learn from previous cohorts and to set an even higher standard for their learning outcomes.

4. WizFolio

Our PBL approach requires students to carry out literature surveys, think critically and write scientifically. Typically, researchers access bibliographic information using expensive applications such as Endnote or Reference Manager. However, we have found a low-cost web-based software called WizFolio (http://www.wizfolio.com) which is a cost-effective alternative for our large classes. While WizFolio is designed to simplify reference management (Figure 4), it has distinctive features such as enabling direct keyword search and allowing users access to scientific papers, which students in our classes are trained to read and critique as part of their PBL information gathering process. In addition, WizFolio also provides a convenient platform for users to share files and references and is thus useful in promoting collaborative learning and teaching. Moreover, Wizfolio has an authoring plugin for Microsoft Word, which most students use to write their final reports. The plugin automatically formats and re-orders citations on the fly according to standard citation styles. It is used in our bioinformatics classes for the authoring and reference management of students' final project reports, according to standards set by scientific journals.

Figure 4. The WizFolio user interface.
Integration of e-Learning Tools with Traditional Lectures and Practicals

The next key step comprises the integration of the e-learning system we described earlier with our traditional lectures and practical sessions. LSM2104/LSM2241 is a compulsory introductory Bioinformatics module, where the class size ranges from approximately 100 to 250 students per semester, while LSM3241 is a more advanced bioinformatics module with a considerably smaller class (approximately 15 to 30 students per semester). Due to the differences in class sizes, variations in students’ competencies and the different projected learning outcomes for both modules, the implementation of the e-learning tools and pedagogical strategy is much more simplified in LSM2104/LSM2241 compared to LSM3241.

Year Three Bioinformatics Class (LSM3241)

For LSM3241, we combine our weekly two-hour lectures with four-hour practical classes. Since the smaller class size facilitates the more intimate teaching and learning style required for advanced, specialised topics, PBL is implemented in full for these classes together with all the e-learning tools we previously introduced, to provide students with the academic rigour required for this course.

![Figure 5. A typical PBL cycle implemented in LSM3241. It begins by introducing a problem scenario, followed by group discussions to propose solutions, the presentation and evaluation of these solutions.](image)

Practical sessions for LSM3241 are divided into two parts: a two-hour hands-on practical session and a two-hour PBL session. BioSLAX is used during the hands-on session to facilitate the learning of relevant bioinformatics skills, where students are free to independently learn and explore the computer applications at their own pace. The PBL session, on the other hand, involves the introduction of a problem scenario, which students are required to solve collaboratively under the guidance of their facilitators (Figure 5). LAMS is used as a teaching tool to present the problem scenario, define the issues to be addressed, assess the students’ understanding of the problem scenario through a series of questions and answers (Q&As) and finally, to provide constructive feedback and critique to the facilitator and their group members (Figure 6). Surveys have been integrated in LAMS during the PBL sessions to collect students’ opinions of these e-learning platforms, and to facilitate any refinement and improvements in the design of the PBL sessions and LAMS sequences. A discussion forum was also created in LAMS to facilitate discussion and exchange of ideas among students. After each PBL session, students are required to record their progress and findings on the MediaWiki site and to prepare a 20-minute class presentation.

![Figure 6. An example of a typical LAMS sequence implemented for a PBL session. The sequence includes using a noticeboard tool to present the problem scenario, followed by a task list tool to define the list of skills to be acquired through the PBL session, a Q&A tool to assess students’ understanding of the problem scenario, a task list tool to define the minimum results required for presentation and a survey tool for students to provide peer feedback and critique.](image)

For the students’ final project report, to be completed by the end of the semester, Wizfolio is recommended for reference management, in-text citations, as well as the collaborative sharing of bibliographic references. We also organised Wizfolio briefing sessions, inviting experts on the programme to give advice and familiarise students with the software.
Towards the end of the course, LAMS is used as an optional e-revision tool to help students prepare for their examinations (Figure 7). The LAMS sequence is designed as a series of multiple choice questions (MCQs) organised under different sections corresponding to each section of the curriculum. It gives students the opportunity to critically assess their understanding of the theories, concepts and practicals covered.

**Year Two Bioinformatics Class (LSM2104/LSM2241)**

In LSM2104/LSM2241, students are divided into affinity groups for the hands-on practical sessions. Each session begins with a problem scenario, which each group has to independently solve by completing a set of instructions and guided questions. After each session, the groups will each take turns to prepare a presentation on the concept and relevant bioinformatics resources applicable to the problem scenario, and they have to record the information on the MediaWiki site.

Like LSM3241, we also recommended Wizfolio to students taking LSM2104/LSM2241 for their final mini report writing, and experts were invited to conduct briefing sessions on how to use Wizfolio effectively. LAMS was also used as an optional e-revision tool towards the end of the course, with the learning sequence comprising a series of MCQs pertaining to different parts of the curriculum, and a survey to solicit relevant feedback (Figure 7).

**e-Learning workshops**

Besides implementing e-learning practices in the formal teaching of our course modules, we also conducted several workshops introducing BioSLAX, LAMS and Wizfolio to educators within and outside of NUS to promote the use of these e-learning tools for educational purposes.

We introduced LAMS and Wizfolio to NUS teaching staff during a one-day e-learning technology workshop jointly organised by the LAMS Foundation and CDTL. In addition, we conducted BioSLAX workshops at the 3rd East Asia Bioinformation Network meeting in 2008 (http://eabn.apbionet.org/3eabn08), as well as the International Conference in Bioinformatics (InCoB) in 2008 and 2009 (http://incob.apbionet.org/incob09/tut-biocloud.html) to introduce the OS to bioinformaticians from various countries. We also introduced WizFolio at InCoB09 and witnessed the signing of the Memorandum of Understanding (MoU) between Wizfolio, a NUS start-up company, the Association for Medical and Bioinformatics for Singapore (AMBIS) and the Asia Pacific Bioinformatics Network (APBioNet), to collaborate on developing new global bibliographic WEB 2.0 service that allows for the easy management of scientific literature for the scientific community anytime or anywhere as long as users have Internet access.

**Evaluation and Assessment**

The survey results collected from students who took LSM2104/LSM2241 and LSM3241 in Semester 2 of AY2008/2009 as well as from participants of the e-learning workshops, have established the usefulness of e-learning tools to complement traditional classroom learning.

**Feedback from undergraduate bioinformatics students**

In general, the majority of the students who took LSM2104/LSM2241 (252 students) and LSM3241 (26 students) agreed that their PBL experience and revision process had been positively impacted by the usage of LAMS to guide their learning and discussion processes, and that the breakdown of PBL activities into a sequential step-by-step workflow by LAMS enhanced their learning experience (see Table 1).
However, the results have also shown that, in contrast to the favourable response from students who took LSM2104/LSM2241, students who took LSM3241 generally did not regard LAMS as a fun and exciting way of learning compared to traditional learning methods.

In terms of the effectiveness of MediaWiki, most students who took LSM3241 agreed that their PBL experience has been enhanced positively through the usage of wiki for documenting the PBL process, coordinating the assignments and compiling the learning issues, hypothesis and conclusions. A detailed evaluation of the usefulness of LAMS and MediaWiki in LSM3241 and LSM2104/LSM2241 classroom teaching and learning has been reported in our recently published article (Lim S.J. et al., 2009).

### Table 1. Summary of responses from students who took LSM2104/LSM2241 and LSM3241. Responses are considered positive when the options “slightly enhanced”, “greatly enhanced”, “agree” or “strongly agree” were checked by students in the feedback forms. No data was available for LSM2104/LSM2241 students’ opinions towards MediaWiki.

<table>
<thead>
<tr>
<th>Question</th>
<th>LSM2104/LSM2241</th>
<th>LSM3241</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience in PBL positively impacted with the usage of LAMS for guiding the learning/discussion (revision - for LSM2104/LSM2241) process.</td>
<td>90%</td>
<td>63%</td>
</tr>
<tr>
<td>Breakdown of PBL activities into a sequential step-by-step workflow using LAMS enhances the learning experience.</td>
<td>60%</td>
<td>63%</td>
</tr>
<tr>
<td>Learning experience of PBL with LAMS was fun and exciting compared to traditional learning methods.</td>
<td>93%</td>
<td>26%</td>
</tr>
<tr>
<td>Will be disappointed if LAMS was removed from PBL process.</td>
<td>59%</td>
<td>47%</td>
</tr>
<tr>
<td>Experience in PBL positively impacted with the usage of wiki for documenting the learning outcomes.</td>
<td>--</td>
<td>68%</td>
</tr>
<tr>
<td>Will be disappointed if wiki was removed from PBL process.</td>
<td>--</td>
<td>37%</td>
</tr>
</tbody>
</table>

Feedback from workshop participants

Participants of the one-day e-learning workshop (24 NUS teaching staff) generally found it useful and applicable to enhancing teaching and learning in NUS, with most of them expressing interest in implementing PBL, LAMS and Wizfolio in their teaching (see Table 2). Most participants agreed that PBL is an effective instructional strategy to enhance students’ participation, thinking and learning. They also felt that it facilitates group interaction and discussion, in addition to promoting independent and critical thinking among students. Most of the participants observed that using LAMS during PBL made the learning experience fun and exciting, compared to traditional learning methods, and that its interactive features were useful for enhancing teaching and learning. All of them agreed that the breakdown of PBL activities into a sequential step-by-step workflow by LAMS also enhanced the learning experience. In addition, most participants recognised that Wizfolio was a hassle-free and user-friendly tool suitable for reference management. Notably, after the one-day workshop, the DUKE-NUS Graduate Medical School initiated a conceptual test of LAMS to be used in their team-based learning sessions and for faculty development.

No feedback data was available for the BioSLAX workshops conducted in InCoB 2008 and 2009, as well as LSM2104/LSM2241 students’ opinions towards MediaWiki and both LSM2104/LSM2241 and LSM3241 students’ opinions towards BioSLAX.

### Table 2. Summary of responses from the participants of the joint LAMS Foundation-CDTL workshop. Responses are considered positive when the options “agree” or “strongly agree” were checked by the participants in the feedback forms.

<table>
<thead>
<tr>
<th>Question</th>
<th>% positive response</th>
</tr>
</thead>
<tbody>
<tr>
<td>WizFolio is a useful tool for reference management.</td>
<td>90%</td>
</tr>
<tr>
<td>WizFolio is hassle-free, easy to use and user-friendly.</td>
<td>73%</td>
</tr>
<tr>
<td>Will highly recommend Wizfolio to students.</td>
<td>80%</td>
</tr>
<tr>
<td>PBL is an effective instructional strategy to enhance students’ participation, thinking and learning.</td>
<td>91%</td>
</tr>
<tr>
<td>Will be interested in implementing PBL in teaching.</td>
<td>83%</td>
</tr>
<tr>
<td>Breakdown of PBL activities into a sequential step-by-step workflow using LAMS enhances the learning experience.</td>
<td>100%</td>
</tr>
<tr>
<td>Learning experience of PBL with LAMS was fun and exciting compared to traditional learning methods.</td>
<td>82%</td>
</tr>
<tr>
<td>Will be interested in implementing LAMS in teaching.</td>
<td>82%</td>
</tr>
</tbody>
</table>
Challenges

**Effective implementation of LAMS as a fun and exciting learning tool**

Based on the feedback from the undergraduate student cohort, it is evident that LAMS needs to incorporate more elements of interactivity, fun and excitement to capture students’ interest and increase their motivation to learn independently. Though it is possible that the lower percentage of positive responses observed among LSM3241 students may be due to their increased frustration and fatigue from having to cope with a heavier workload, this nonetheless highlights the need for e-learning tools in general to be made more interesting and engaging to students. In this regard, more improvement and fine tuning will be required for existing e-learning tools to increase their interactivity without increasing students’ workload. Similarly, the same level of interactivity, if not higher, will also be expected of newly developed learning tools.

However, due to its emphasis on collaborative efforts and group interaction, PBL, in general, appears to be more appropriate for small group teaching. Therefore, realistically speaking, the implementation of PBL and LAMS may be more feasible for smaller classes (comprising 10 to 15 students) where resources such as facilitators and computers are available. Consequently, another challenge lies in implementing PBL and LAMS effectively in large classes (e.g. LSM2241 with 252 students), especially when it involves synchronous teaching. In this context, breaking down a large class into smaller PBL discussion groups may pose difficulties due to resource limitations. For such classes, it may not be feasible to implement PBL, and LAMS may only be reduced to a revision tool. In view of these inherent limitations, we have to explore more effective ways of implementing PBL and LAMS in large classes. Alternatively, a future direction could involve adopting other novel teaching and/or e-learning strategies that are more applicable for large classes. This challenge highlights the important fact that e-learning tools must be able to support and run in synergy with implemented classroom pedagogical strategies for maximum efficiency.

In addition, since most e-learning software will be continually updated with new features and functions, another challenge lies in the continuous training of facilitators to ensure that they are well-equipped with up-to-date knowledge of e-learning applications. In view of this challenge, active acquisition of information and updates, as well as regular training and briefing sessions for the facilitators, have to be undertaken continually.

**Harnessing the cloud**

Another limitation of implementing e-learning technologies in education, particularly for server-based e-learning software, lies in the hardware (server) itself. A server used for hosting e-learning software has to manage a considerably high amount of network traffic and server load, thus requiring high speed and performance. One possible way to overcome this challenge is to upgrade our existing servers or seek existing hosting services. However, taking into account the projected expenses and server maintenance costs, such an option is not cost-efficient in the long run.

In this regard, cloud computing services represent a potentially cost-effective solution for server hosting. Cloud computing services such as Amazon and GoGrid offer virtual, scalable servers with pay-as-you-go pricing plans where users are charged in terms of usage. In this way, e-learning servers can be turned off when they are not needed (e.g. during the vacation period) to save costs. Furthermore, the performance of cloud servers can be scaled up or down according to the projected amount of traffic and load. Besides cost and technical advantages, cloud servers, much like the BioSLAX OS, also provide a platform for customised and personalised learning in which individual server instances can be created for each user.

In view of the advantages offered by cloud computing services, we have hosted BioSLAX and LAMS on cloud servers which are accessible to students.

**Conclusion**

Our experience and results have shown e-learning applications to be promising for supplementing PBL in bioinformatics education. The main benefit of PBL over traditional teaching methods lies in the fact that PBL promotes independent and collaborative teaching and learning through group discussions with minimal guidance from the facilitator. In this respect, e-learning tools like BioSLAX, LAMS, MediaWiki and Wizfolio are useful in complementing PBL by providing the necessary resources and support for the tasks involved in learning, teaching and monitoring. On the other hand, customisable e-learning tools like LAMS and BioSLAX offer educators exciting opportunities to provide flexible, personalised and specialised learning to complement traditional classroom teaching.

Though certain limitations and challenges are present, taken together, the feedback and response from both students and staff have been encouraging and provided the impetus for the further development and implementation of useful e-learning technology, not only in bioinformatics education, but in other disciplines as well.

More sophisticated e-learning software and platforms such as cloud computing will emerge in the future. The work of integrating e-learning tools into our teaching and learning will continue. We hope that some of these tools can be incorporated directly into the IVLE. In this way, all teaching staff can easily evaluate their usefulness and deploy appropriate e-learning tools in the teaching of suitable subjects such as bioinformatics.

**Acknowledgements**

This work was fully supported by the Teaching Enhancement Grant (TEG) from the Centre for Development of Teaching and Learning, National University of Singapore.
References


