MATHMATICS ONLINE – A LEARNER CENTRED TUTORIAL SYSTEM DEVELOPED BY AND USED AT Ngee ANN POLYTECHNIC

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Abstract

Mathematics is an important subject that all Engineering students need to master as it serves as foundational knowledge for many engineering disciplines. The mathematical abilities and learning styles of the students at polytechnic level are very varied. To harness the advancement in technology and computer assisted learning, add value to the learning experience of students and promote independent learning, Ngee Ann Polytechnic (NP)'s team of mathematics lecturers spearheaded the development of the Mathematics Online (MOL) system. The system has undergone several phases of enhancements since it was first launched and it is still actively in use today.

MOL is a self-paced, learner-centred tutorial system, comprising tutorial questions with worked examples, as well as an assessment component. It allows students to attempt unlimited practices of basic-level questions to strengthen their mathematics foundation.

This paper will present and discuss key features of the effectiveness and efficiency of MOL which include the following:
1. Customisable practice question sets
2. Empowerment of learners
3. Immediacy of feedback to learners
4. Self-monitoring feature for students
5. Progress monitoring feature for staff
6. An adaptive assessment system

This paper will also share how the features of MOL have benefited students’ learning. Quantitative data from a student survey demonstrate the impact of MOL on students’ perception of their learning in areas such as thinking and self-directed learning.

Keywords: mathematics, online tutorial, independent-learning, adaptive assessment, customised practice, immediate feedback.

Introduction

Teaching methodology is always evolving, especially in the 21st century, the age of technology. In Ngee Ann Polytechnic (NP), the teaching of mathematics was no longer restricted to chalk and board when the idea of an online tutorial system in mathematics was first mooted in the 1990s. Thus, Mathematics Online (MOL) was designed to embrace e-learning for borderless teaching and learning. This also supports business continuity by moving away from traditional face-to-face lessons confined to a classroom.

Literature reviews released over the last decade verify that there are good reasons to develop an online learning system in mathematics, riding on existing computer software with mathematical capabilities. MOL was ahead of its time when it was created in the late 1990s.

Computer algebra systems (CAS) are well-established software for performing manipulation of mathematical expressions (Naismith & Sangwin, 2004). CAS has the ability to correctly assess whether two expressions that are presented in different forms are algebraically equivalent. CAS is also able to mark an answer by checking it against each required condition separately, a procedure that could be extremely laborious if done manually (Sangwin, 2003, 2004). In addition, a CAS is also able to generate unlimited questions with random parameters. By using random parameters, each student can receive a unique set of questions, which may assist in reducing plagiarism (Naismith & Sangwin, 2004). MOL was developed with all the above capabilities and features in mind using Scientific Notebook which has a built-in CAS (Maple in earlier versions and/or MuPAD in later versions).

The increasing availability of computers and internet technologies has thus led to a surge in the number of online mathematics portals which allow students to learn mathematics independently such as Khan Academy, Purplemath, IXL Math, National Library of Virtual Manipulatives, and ASKnLearn.

On the other hand, in designing effective e-learning systems, it is necessary to understand the target population (Liaw, 2004). Learner characteristics, such as self-efficacy, self-directed behavior, and autonomy need to be identified (Passerini & Granger, 2000). Environmental characteristics, learners’ attributes and instructional structure should be taken into consideration when developing e-learning systems (Liaw and Huang, 2007).

Advocating the above views, MOL was developed as an integrated learning system that has dual purposes, as (i) an online tutorial platform and (ii) an adaptive assessment tool. It stands out from other typical e-courseware as it has an adaptive assessment component that are lacking in many free courseware available on the internet.

According to Bechard, Kahl and Hill (2004), adaptive tests are structured such that items are presented in an increasing order of difficulty. Students may continue taking the test as long as they answer items correctly or do not respond with a certain number
of incorrect answers in succession. The underlying assumption is that the student is unable to correctly answer any other more difficult items once one or more incorrect answers were given. It is with this design approach in mind that the MOL adaptive assessment component was conceived.

**MOL as a comprehensive online tutoring system**

MOL was developed by NP mathematics lecturers with a question bank of around 2350 mathematics problems. Being an online platform, students are able to access it at their own time, and have control over where, when and how often to access MOL for practice.

*Promoting self-learning*

Independent learning takes place when students study an example with detailed solution that is available on MOL before attempting to solve associated exercise questions. Figure 1 shows a sample of a typical MOL example with full solution.

![Figure 1. A sample example in MOL.](image)

As this helpful guide is made available for every topic on MOL, students may choose any topic(s) to learn, providing them the opportunity and space for effective self-learning.

*Customising practice question sets*

MOL was developed to meet NP mathematics requirements of various diplomas offered across different disciplines of Engineering, Health Sciences and Life Sciences.

In practice, the lecturer in-charge of each module will select exercise topics for his/her module at the start of each semester. This customization means that the exercises can be selected according to the specific module syllabus and also pitched at the right level of difficulty for that cohort of students.

*Providing immediate and specific feedback to learners*

MOL is able to provide unlimited questions for students who wish to have more practice to better grasp concepts learnt and be familiar on how to apply them in solving mathematics problems.

Each time a student attempts a question in MOL, the system generates the question from a fixed template but with randomised parameters. In this way, two students doing the same exercise will see different questions that test the same skillset. Even if the same student attempts that particular question again for the second time, he will see a new question. Figure 2 shows a sample question in MOL.

![Figure 2. A sample question in MOL.](image)

Students may repeat the practice as often as they wish until they are satisfied with their level of proficiency. The practice is marked immediately by the system and students receive instant feedback for every answer. The system, together with its huge pool of related examples, is available 24/7, to help students reinforce their mathematical skills.

When an answer is submitted, the system acknowledges whether the answer is right or wrong for the student's reference. In the event that wrong answers are submitted, students receive immediate feedback and are given step-by-step solutions, including relevant formulae where appropriate. Figure 3 shows a sample of such typical response.

![Figure 3. A typical response/feedback displayed in MOL upon receiving a wrong answer input.](image)

Students may re-attempt the practice questions until they get the right answers. Therefore, with each attempt on an MOL exercise, students can clarify their misconceptions and hopefully, through enough practice, build their confidence in mathematics.
Monitoring students’ progress

MOL also provides every student with an online progress chart with information on each question to be attempted. The progress chart indicates if each of these questions is answered correctly, incorrectly or yet to be attempted per topic. This feature allows students to plan their own learning and acquire skills at their own pace, time and place.

At the same time, staff tutors are awarded access rights to monitor students’ progress. Tutors are also informed on the amount of time each student spent working on specific questions, thereby identifying the need to revise particular topics deemed difficult by the students.

Throughout the semester, tutors may opt to periodically display the entire class’ progress to students to instill a sense of competition, motivating students to accomplish more. Good students feel a sense of satisfaction that their rapid progress has been captured by the system while slower students feel a sense of urgency to catch up with the rest of the class.

MOL as an adaptive assessment tool

Every topic in MOL ends with a ‘Revision’ component that is adaptive in nature. All questions in the MOL bank are pegged to one of the three difficulty categories with category 1 as the lowest difficulty. At the start of a Revision, MOL presents the student with a set of category 1 questions. If those are answered correctly, the student is allowed to move on to category 2 questions. On the other hand, if the category 1 questions are answered incorrectly, MOL will continue with questions of the current category of difficulty. This iteration continues until the learner has achieved the required standard set by the program. Thus, a stronger student will take a shorter time to complete the MOL Revision compared to a weaker student. Figure 4 shows the flow chart of the MOL Revision.

The adaptive assessment algorithm is good because our students possess a very diverse range of mathematics proficiency. At one end of the spectrum are international students and those who had taken Additional Mathematics in their secondary schools, both of whom have stronger mathematics background. At the other end of the spectrum, we have weaker students who might not have taken O level Elementary Mathematics. Thus, an adaptive teaching and assessment tool like MOL is very appropriate for our situation where it is common to find a very diverse mix of students even within one class. The stronger students enjoy the satisfaction from completing some tasks faster than others, allowing them to advance to further topics, while the weaker ones appreciate that they can have more time to practice on their demand.

Figure 4 also shows that if a student gives too many consecutive wrong answers, the system will automatically ‘pause’ the Revision and prompt him or her to seek remedial help. The staff tutor will then provide the said student extra coaching and upon meeting some level of proficiency, grant him/her re-entry to the system.

This mechanism also serves to discourage students from trying their luck with mindless answers. MOL takes appropriate action against such learners by forcing them to work through solutions in a proper manner; otherwise, they risk going through the longer route in completing MOL Revision.

![Image of algorithm](image-url)

Figure 4. Algorithm of MOL’s adaptive assessment.

Unlike the Exercises which can be practised at one’s own time and pace, the MOL Revision component is attempted by students in the presence of their tutors during formal class time. This ensures that the Revision exercises are genuinely completed by students themselves and not by proxies. Tutors can verify the name of each student as it is displayed on the respective student’s MOL page.

In summary, the MOL Revision is appropriately designed for today’s classroom situation which sees a wide spectrum in the mathematics proficiency levels of students. It has an adaptive assessment mechanism that works well in managing a class of learners with varied-ability. It has features to incentivize and motivate, as well as a control system to discourage effortless and mindless answer inputs.
Students' feedback

A survey was conducted in June 2013 to gather students’ views on the use of MOL. 743 students responded and the results of the survey are summarized in Figures 5, 6, 7 and 8.

Figure 5. MOL promotes thinking

Figure 6. MOL promotes independent learning

From Figures 5 and 6, more than 90% of students agreed and/or strongly agreed that MOL promotes thinking and helps them to cultivate independent learning habit. It is very encouraging because students feel a sense of ownership and take control of their own learning.

Figure 7. MOL is helpful in the learning of mathematics

Figure 8. MOL provides helpful feedback

Figure 7 shows that 90% of students were able to appreciate the relevance and benefits that MOL offers in supporting their studies of Engineering Mathematics. The MOL is a source of help that is very practical especially when students need help outside the scheduled classroom meetings. This view is echoed again in Figure 8 that shows 80% of students agreed and/or strongly agreed that MOL provides helpful feedback.

Overall, the survey results indicate the effectiveness of MOL and its popularity with students, with more than 80% of them finding it a useful tool for thinking and learning. We are heartened by the positive response and appreciation by the students, which has in turn motivated us to enhance MOL further.

Future Development

Although MOL has served students well and attained some degree of success, there are two areas for potential development in the future.

Firstly, students and staff have to access MOL using notebooks or desktop computers at the moment. If MOL could be reconfigured to be more mobile-friendly, students will be able to access it from any mobile devices, which may translate to greater participation.

Secondly, we believe it is beneficial to tweak and enhance the adaptive nature of MOL assessment. With the current algorithm, students are always working from easy to difficult questions. It will be useful if students can start with middle-level questions and then move on to either easier or harder questions depending on individual student’s ability.

Conclusion

MOL is a robust, integrated system that has dual purposes. As an online tutorial platform, it promotes a learner-centered mathematics learning culture in Ngee Ann Polytechnic. As an adaptive assessment tool, it helps educators set assessment that caters to different needs of students of varying abilities. It helps students to diagnose their weakness and then directs them to relevant questions for more practice to overcome the weakness before progressing to the next level.

Survey results have shown that MOL is well received by the students. Students find it useful in helping them to strengthen their foundations in mathematics and it certainly enhances their learning of Engineering Mathematics in the polytechnic.

In conclusion, MOL has proven to be a popular self-learning tool that is learner-directed and adaptive. It has supplemented classroom tutoring and has relieved the tutor with more time to guide those who need personal one-to-one coaching. The success in its design lies in its user-centredness, customisability and immediacy of feedback, amongst other strong features. It has made the learning of mathematics an effective and unique experience at Ngee Ann Polytechnic.
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References


