ENHANCING STUDENT PERFORMANCE IN FIRST YEAR CHEMISTRY THROUGH WEB-BASED LEARNING IN AN OPEN DISTANCE UNIVERSITY CONTEXT

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ABSTRACT

This paper reports the results of a study to assess the impact of MasteringChemistry® on student performance in chemistry. The proprietary MasteringChemistry® is a web-based tutoring application and assessment system currently used in first year chemistry modules at the University of South Africa (Unisa). This web-based programme provides supplementary work, giving students practice with instructor-assigned problems. The system is able to coach students with feedback specific to their needs and with simpler problems upon request. The application also provides the individual student with immediate and specific feedback on incorrect or partially incorrect answers. There is great potential for web-based learning in an open distance-learning environment. In particular, in subjects such as chemistry where problem-solving strategies are intrinsic to the learning process, the internet could be an effective medium for teaching and learning. The rationale for this study was to explore new teaching strategies to increase the pass rate in chemistry. A profile of

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the student demographic, with data gathered from registration records, is presented. Data collection on student assessment occurred through the instructor diagnostic tools in the MasteringChemistry® application or with the assistance of the Unisa Examination Administration. Here we present preliminary results that indicate that most students who regularly accessed the material achieved better examination results than those who did not. This pilot study has led to improved and innovative formative assessment practices by the academic staff in the Chemistry Department at Unisa. It further formed an interesting and challenging learning experience for staff investigating web-based approaches directed at improvement of their assessment activities.

Keywords: General chemistry; course design; on-line tuition support; interactive web-based learning; online assessment; formative assessment; Open Distance Learning (ODL).

INTRODUCTION

Historically, distance education was defined as studies by students not under direct and continuous instructor supervision (Holmberg 1989), while a more recent definition refers to education where the student and instructor are physically separated by a geographical distance (Moore, Dickson-Deane, and Galyen 2011). Recent advances in technology have allowed distance education to evolve from a traditional correspondence model to one that incorporates online learning into the course itself (Harasim 2011). Online learning is considered to be the latest form of distance learning that grew from advances in technology (Downing and Holtz 2008). While no standard definition of online learning exists, it is described by most authors as access to learning experiences via the use of some form of technology (Conrad 2002; Carliner 2004; Moore et al. 2011) in which the internet serves as the primary environment for course interaction and discussion (Harasim 2000). The key feature of online learning is accessing the internet for educational purposes. Until recently, the University of South Africa (Unisa) was primarily a correspondence university, with assessment being done mainly through written assignments and printed matter, which Heydenrych and Prinsloo (2010) have classified as 'first generation distance education'. A textbook was prescribed, and students were provided with a study guide, detailing how they should approach their studies and how to study the content. However, Unisa has now adopted a blended approach to formative assessment, and lecturers are encouraged to use a combination of different assessment methods (Khoza 2011; Van Rooy and Madiope 2012), including written assignments and online assessments. Prior to the blended approach, the module General Chemistry 1A was assessed by means of three written assignments, followed by a summative assessment in the form of a two-hour written examination at the end of the term. After submission of each assignment by the student, the assignment was marked,

and a detailed memorandum was provided to students, which was followed up by a tutorial letter which detailed common problems observed in the assignment answers and contained recommendations as to how students should approach these topics in general. However, the lack of immediate feedback, and the small number of written assignments (which, for logistical reasons, could not easily be increased) were still a problem. As has also been found in other South African institutions with Open Distance Learning programmes, we discovered that many of our students are not successful at their first attempt and only pass the General Chemistry 1A module after a second or third examination (Geduld 2013). In an attempt to decrease the transactional distance (Moore 1993), we revised the assessment methods in the module so that it includes an online component, which allowed for an increased number of tasks, immediate feedback to students, and mixed assessment methods, particularly in areas of the subject with which students are known to experience difficulties. We wished to determine whether the implementation of online assessment was indeed useful in increasing the pass rate and pass mark of these students. In the following section, we provide background to the use of online assessment at Unisa. This is followed by a description of our methodological approach and results. We conclude this article by providing recommendations for the implementation of MasteringChemistry® as a formal online assessment tool in an ODL environment.

BACKGROUND

A major challenge faced by distance education academics is finding effective online teaching strategies which use the varied technologies now available, especially in the field of chemistry (Brooks and Crippen 2001; Ardac and Sezen 2002; Cole and Todd 2003; Crippen and Boyd 2007; Frailich, Kesner and Hofstein 2007). This is evident in Pienta's editorial article entitled 'Online courses in chemistry: Salvation or downfall' (2013), and in a recent review article in the *Journal of Chemical Education* by Leontyev and Baranov (2013) which highlights the plethora of online platforms available and their features, which have been designed in an attempt to enhance teaching and learning in the field of chemistry. At a distance university such as Unisa, there is very little contact between lecturers and students, and one of the challenges which we have identified in teaching chemistry through distance methods is that it is difficult to provide enough opportunities for students to work through sufficient problems to master certain chemistry concepts with which they struggle. The last decade has seen rapid development in the use of the internet in science education. This trend has led to the development of a number of web-based tuition support programmes in chemistry, such as the proprietary Online Web-based Learning (OWL) (Evans 2009) and MasteringChemistry® (Shepherd 2009) applications as well as a host of in-house developments at a number of universities. (Steyn, Alexander and Rohm 1996; Freasier, Collins and Newitt 2003; Nick, Andresen and Lübker

2003; Korkmaz, William and Harwood 2004; Lowry 2005; Leontyev and Baranov 2013) MasteringChemistry® has been used in several residential universities as a supplementary teaching tool[1] but never as a primary formative assessment tool in an ODL context. To our knowledge, Unisa is the first university to implement MasteringChemistry® as a complementary method of formative assessment in an ODL context, and we wished to evaluate the impact of the use of this technology on the pass rate for the General Chemistry 1A module.

Apart from the few articles cited in this paper, very limited literature on MasteringChemistry® and similar online platforms and their use for online assessment in chemistry is available, as is clearly stated by Belland (2009, 5): 'A search with ERIC for literature on comparing the use of different Web-based homework systems reveals no other studies of this topic; evidence that this study is unique within the subject of chemistry'. Our review of existing literature confirms this statement. However, we have confirmed through private communications that MasteringChemistry® *is used in contact* universities,[1] further highlighting the need for formal studies on the impact of such platforms on teaching and learning chemistry.

We have used MasteringChemistry® in the General Chemistry 1A course at Unisa since 2010. The programme was bundled with the second edition of Brown, Lemay, Bursten, Murphy, Langford and Sagatys' *Chemistry: The Central Science: A Broad Perspective.* A number of problem types are available in the programme, varying both in content (symbolic, numeric, conceptual) and answer style (multiple choice, short answer, essay, graphical sorting, molecular drawing, and graphs). Task settings can be adjusted to enable students to attempt the problem until they get it correct. Students are also allowed to repeat problems until the deadline date set by the instructor. While students are still able to work on problems after the deadline, no credit for these tasks is awarded.

The demographics of the students registered for General Chemistry 1A are shown in in Figure 1. These demographics reflect the typical profile of students who register for this module. The students registered for this course came from a broad range of backgrounds. They were mainly school leavers who had entered university directly after school. In addition, for most students, English is not their first language.

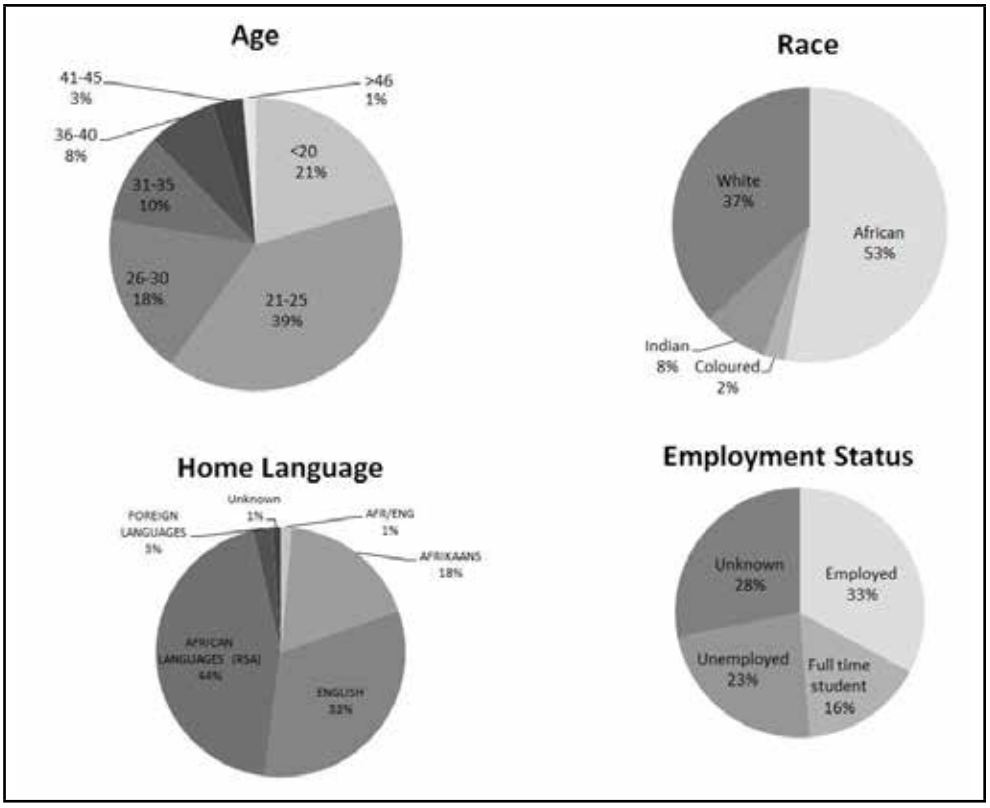

Figure 1: Demographics of the General Chemistry 1A student.

METHODOLOGY

At the start of Term 1 of the 2010 academic year General Chemistry 1A students were informed of the availability of the MasteringChemistry® as an optional learning activity. The questions assigned online covered a significant part of the curriculum that had to be mastered for the course. Students could either purchase the textbook which included the access code to register an account on the MasteringChemistry® website or alternatively purchase the access code only, which also granted them access to an electronic copy of the textbook. The access code allows student to use the MasteringChemistry® resources for 18 months (3 terms). Information on the procedure to create an account on MasteringChemistry® and on how to access the assigned activities was supplied to students. Students had access to a student user guide as well as online technical support directly from the MasteringChemistry® website.

MasteringChemistry® is an online assessment programme designed to provide students with personalized tuition and individualized feedback to help

improve problem-solving skills. The programme provides a self-regulating learning environment suitable for independent study which enables students to work at own at their pace. The system provides the student with hints and immediate feedback specific to individual misconceptions so that students can correct their mistakes. MasteringChemistry® provides hints of two types that help students work through, and ultimately solve, problems: Declarative hints provide advice on how to approach the problem, guiding students to the final answer. Socratic hints (Heeren 1990) break a problem down into sub-problems, which makes it easier for students to complete the original problem. It was made clear to students that the use of the software was entirely optional. Data collection involved the extraction of students' results from the MasteringChemistry® application and their final examination results were obtained from the Unisa student system. Final examination scores were used as a general performance indicator.

The 'Diagnostics View' in MasteringChemistry® gives a comparison between the students' performance and the global difficulty level and scores for a certain question, as well as a comparison between the average times taken to do a question by the students as compared to the global average. Figure 2 shows a typical 'Diagnostics View' of students' performance in a MasteringChemistry® task. The diagnostics tools in MasteringChemistry® have been especially useful in enabling us to determine in which areas the students have difficulties. For example, we have determined that questions on isotopes and atomic mass are not of high difficulty globally, but that students in our General Chemistry 1A course performed badly in this problem set. Using the information provided by the diagnostics tools, we have been able to identify the major gaps in our students' understanding of certain areas of the curriculum, for example, chemical bonding, bond polarity, quantum numbers and Lewis structures, and we have redesigned our course material accordingly. The information provided by the diagnostic tools is being used on a continuous basis to improve the content of the General Chemistry 1A course.

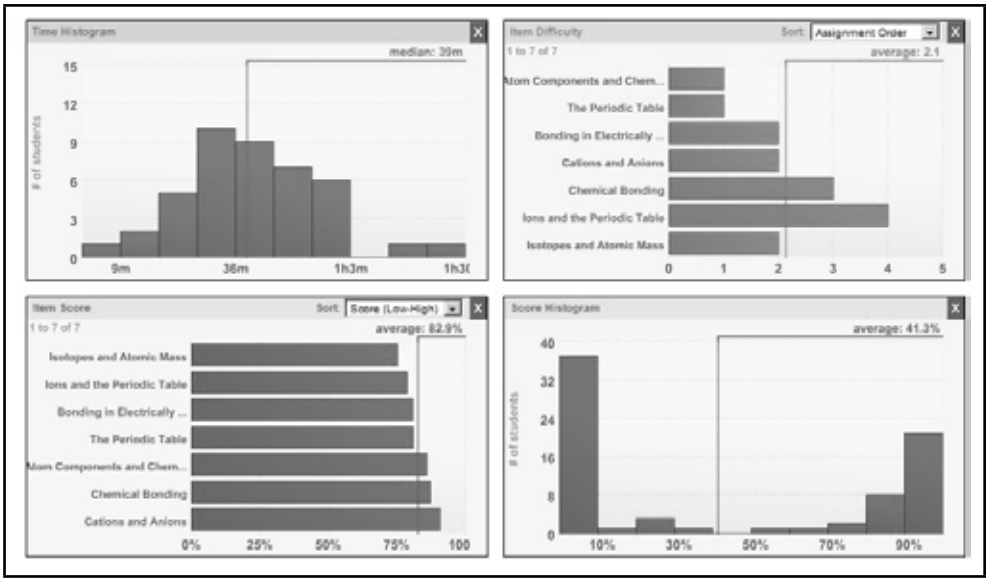

Figure 2: A typical Diagnostic View of students' performance in a MasteringChemistry® task.

This study presents one term's worth of data in an ongoing project. While the web-based learning system in this study was open to all students, usage was not compulsory and the results obtained in the tasks did not contribute to the student's final pass mark. The population of the study consisted of 415 students who wrote the General Chemistry 1A final examination in term 1 of the 2010 academic year. Of these 415 student, 65 students chose to do some or all of the tasks set on MasteringChemistry®. The sample was divided into three populations: the unguided student who did not use the MasteringChemistry® programme (n_1), the semi-guided student who completed 50% or less of the tasks assigned (n_2) and the fully-guided student who completed more than 50% of the tasks assigned (n_3).

Four curriculum-based activities, from the MasteringChemistry® programme, were assigned to the students (See Table 1). Each activity consisted of tasks to guide the student through selected topics in the chemistry syllabus with self-paced tutorials that provided individualized instruction. Each task consisted of a number of questions covering a section of the curriculum. The questions in these tasks were designed to guide the student through the more difficult topics in the syllabus. This afforded the students more opportunities for working through important chemical concepts and practice at solving chemical problems. While multiple choice and essay type questions are available in the programme, these were not used in our study. Student usage was monitored on a continuous basis using the instructor tools available in the programme. The MasteringChemistry® programme incorporates a variety of instructor diagnostic tools including problem time and difficulty, which are

useful indicators for both individual and class performance. A gradebook function is available with scores colour-coded in the web-browser, which makes it easier to see which students are having difficulty as well as which topics are proving the most difficult. Besides student scores, we also reviewed the amount of time each student spent on completing the tasks. The primary goal of this study was to establish whether there is a relationship between use of the web-based learning tool and increased student performance.

Table 1: Summary of activities assigned in MasteringChemistry®

Activity	Topic	Questions assigned focused on
1	Atomic Theory and the Periodic Table	Atom Components and Chemical Symbols The Periodic Table Cations and Anions Chemical Bonding Ions and the Periodic Table Isotopes and Atomic Mass
2	Electronic Structure of Atoms and Chemical Bonding	Orbital Diagrams Quantum Numbers The Bohr Equation Electron Configurations of Ions
3	Lewis Structures	Drawing and Predicting Lewis Structures
4	Molecular Geometry and Bonding Theories	Octet Rule Bond Polarity Formal Charge of a Diatomic Molecule Exceptions to the Octet Rule Formal Charges and Resonance

RESULTS AND DISCUSSION

There are two clear effects of the introduction of MasteringChemistry® on the students' performance: (i) the effect on the pass rate in the General Chemistry 1A module and (ii) the effect on the final pass mark obtained by the students. The result of each of these effects is discussed below.

Regarding the pass rate, the required pass mark for the General Chemistry 1A module is 50%. Of the unguided population of students, who did not use MasteringChemistry®, 43% passed the course. In comparison, 80% of the semi-guided population passed, and 100% of in the fully-guided population passed the course. Of the total population of students who used MasteringChemistry®, 83% passed the course. The use of MasteringChemistry® therefore corresponds to a significant increase in the pass rate, in so far as it more than doubled the pass rate of the students who did not use MasteringChemistry®.

The effect of the introduction of MasteringChemistry® on the final pass mark of the students was also significant. As Unisa is a distance university, its General Chemistry 1A students do not have the opportunity to engage in continuous test and examination-type assessments throughout the term as students at contact universities do. Rather, the summative assessment consists of a single two-hour examination written at the end of the term. Our results show that the number of tasks performed on MasteringChemistry® had a clear and significant effect on the final pass mark achieved in this examination. Figure 3 shows the final average percentage obtained by the students versus the number of tasks performed by the students. The average pass mark obtained by the unguided population who did not use MasteringChemisty® was 47%, whereas the semi-guided students averaged 62%, and the average pass mark of the fully-guided population was 74%.

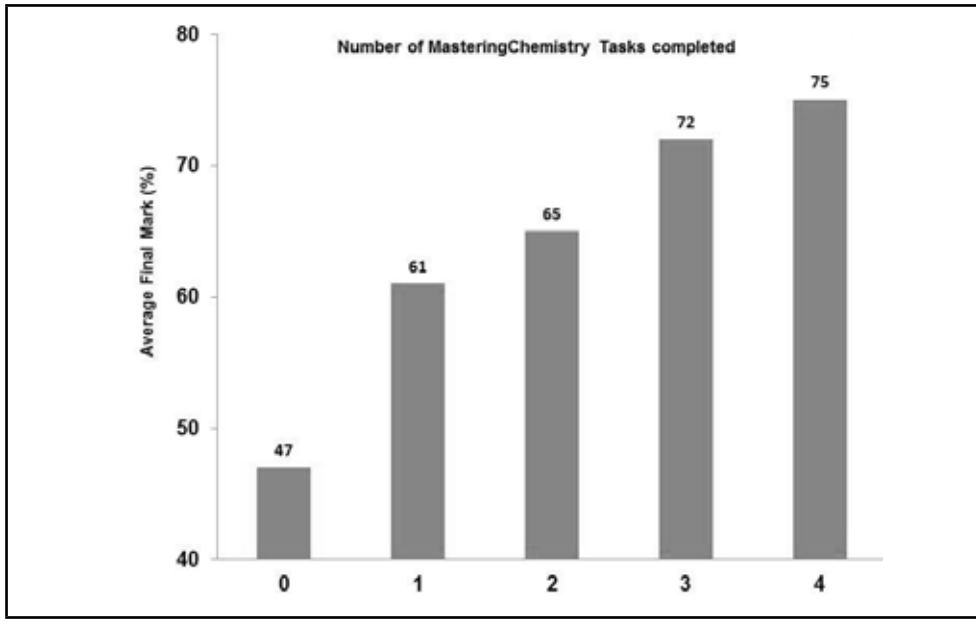

Figure 3: Final average percentage obtained versus the number of tasks performed by the student.

In order to improve our implementation of MasteringChemistry® on an ongoing basis, including the way in which we structure the course activities, the time required for each activity, and the ease of access to the programme, students were invited to provide feedback on their experience in using, and perceptions of, MasteringChemistry®. In general, there was a positive response from the students to the introduction of MasteringChemistry®. Selected student comments as posted on myUnisa are presented below (with permission):

> Mastering Chemistry is great! But I have to admit that it takes definitely too long. I am full-time employed. I struggled to complete the Introduction to Mastering Chemistry in one night. It also doesn't save my questions so I have to start all over again if I don't have enough time in one evening. It's a fantastic tool but the implementation is still faulty. Regards, T. Breytenbach
>
> Just to emphasize that I think MasteringChemistry® is a great idea, but the stress of tasks with deadlines is not too cool, especially considering the delay with the textbook in stores as well as the fact that we also have an assignment due tomorrow. Would be nice to have a little helper that doesn't come with more stress. M. Bingham
>
> I love the Mastering Chemistry, I used the same platform for the BLG [biology] modules last year and find it certainly helped me picture the concepts i was studying… - so yes, Mastering Chemistry is helping me a whole bunch! The tasks do take a long time, but they are helpful. It seems I am way behind on covering the text required for the tasks so I may not be able to complete them in time for the cut off - will they still be available to complete after the due date? Perhaps for those of us that are taking longer to cover the work we can use this as revision for the exams? C. McGee

All the comments that we received were carefully considered, and we have made adjustments to the structure of the activities accordingly. A major criticism was that the tasks were too long and that students preferred more but shorter tasks which could be completed in several sessions, rather than in one long stretch. We have since implemented this suggested change and received a positive response.

SUMMARY AND CONCLUSIONS

Results from this study suggest that web-based tuition support as provided by MasteringChemistry® is an effective means of enhancing student performance in first level chemistry modules at ODL universities. The pass rate of students who used MasteringChemistry® was more than double that of those who did not. The number of MasteringChemistry® tasks completed by students had a clear and significant effect on the final pass mark achieved in the examination. Improved results may be attributed to the Socratic approach of the MasteringChemistry® programme that has been designed to enhance the problem-solving skills of students. Due to the success of this pilot study, MasteringChemistry® is now used as the primary mode of formative assessment in General Chemistry 1A. It has also since been successfully implemented

in the follow-up first year chemistry module, General Chemistry 1B. The use of MasteringChemistry® has recently been made compulsory for these modules, and the results thereof are currently being monitored and analysed. Based on our results and analysis, we recommend the use of MasteringChemistry® as a primary online assessment platform for formative assessment for first-level chemistry in an ODL context, as we have found that it decreased the transactional distance in this context, enhanced the problem-solving skills of the students, increased the pass marks of those who used it as compared to those who did not, and dramatically improved the pass rate in our general chemistry module.

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NOTES

1. Contact universities at which MasteringChemistry is used as a teaching tool are: Michigan State University, USA; University of Canberra, Australia; University of North Florida, USA; University of Kwazulu-Natal, South Africa; University of the Witwatersrand, South Africa.

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