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Online learning
Is it meant for science courses?

Lau Seng*, Fitri Suraya Mohamad

Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

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Abstract

The authors discuss a case study experience in conducting scientific courses such as Environmental Chemistry and Spectroscopy to different groups of undergraduates at Universiti Malaysia Sarawak (UNIMAS), using web-based learning environments to support conventional teaching/learning sessions. The authors discovered that by supplementing the learning online, students became more interested in their respective fields of study, and thus were able to participate in class discussions more freely. Online, a higher number of group activities can be organized to consolidate the learning of specific topics. The web-based learning environment also allows more interaction opportunities between peers and with the course instructor. Overall, the students reported they found that learning online made the course more interesting, and that the students were consciously aware that they learned more in the process. The paper also highlights the major benefits of conducting a course online from a course instructor's perspective.

Keywords: Online learning; Science courses; Teaching science; Student participation

1. Introduction

Students often comment that science courses are dry and boring. Many educators ignore such perceptions or give excuses indicating that science subjects are fundamentally abstract in nature; hence, there are no interesting ways to teach science courses. However, such conserv-

* Corresponding author. Tel.: +60-82-671-000; fax: +60-82-671-903.
E-mail address: lauseng@frst.unimas.my (L. Seng).

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ative perception is slowly being eroded, giving way to more innovative approaches to teaching science. Audiovisual aids, modeling techniques, and live demonstration approaches have been widely used in teaching science, resulting in some degree of success. The main setback of these approaches is that students may not be able to use those teaching aids while revising their work. In this paper, the authors discuss a case study experience in conducting scientific courses such as Environmental Chemistry and Spectroscopy to different groups of undergraduates at Universiti Malaysia Sarawak (UNIMAS), using a web-based learning environment to support conventional teaching–learning sessions. The authors discovered that by supplementing the learning online, students became more interested in the fields of study, and thus were able to participate in class discussions more freely. Online, a higher number of group activities can be organized to consolidate the learning of specific topics. The web-based learning environment also allows more interaction opportunities between peers and with the course instructor. However, there were some notable technical limitations encountered during the use of the web-based technology. These barriers will be discussed further in the paper. Overall, the students reported they found that the online course was more interesting, and that they were consciously aware that they learned more in the process. The paper also includes highlights of the major benefits of conducting an online course from the instructor's perspective.

At UNIMAS, conventional teaching methodologies mainly depend on delivering the bulk of course materials to the students in a monologue lecture environment. Frequently, the lecture material comes from predetermined texts, giving students little incentive to attend and participate in class. The learning environment is always passive, and very often these undergraduates find themselves lost in the process. In particular, undergraduates report that they are lost when they deal with the more technical and scientific concepts and principles, which tend to be incomprehensible, or detached from real-world contexts. Only a handful of exceptional university instructors are capable of holding students' attention for an entire lecture period. The conventional teaching approaches seldom provide adequate opportunity for students to critically think through the issues and arguments presented in class. The students are either too busy scribbling down notes from the lecture, or trying very hard to make sense of the rhetoric of the lecture. Consequently, the pure lecture format simply reinforces students' feelings that the most important step in mastering the material is memorizing large amounts of scientific information from chunks of seemingly unrelated examples.

Many pioneering chemistry educators have long expressed the need for students to understand chemical knowledge rather than the isolated use of "algorithms" or memorization of data and facts. Some expressed the pedagogic need for students to link the solving of quantitative problems to the corresponding underlying chemical principles. Overall, many of the articles written by these pioneering educators focused on the need to advance the fundamental pedagogic ideas in chemical education (Suits, 2001). Some chemistry educators have found that by posing puzzles that challenged the imagination of students and by making lectures livelier, such have helped students retain information longer than through conveying straight and direct statements of fact and principles (Bartell, 2001a).

It is rather common that students hear horror stories about how tedious and difficult thermodynamics courses are. It was found that through giving a collection of vignettes, either recounting the personalities of some of the architects of thermodynamics, or through noting

steps and missteps in the development of thermodynamics, and with kinetic theory combined with a set of stories illustrating thermodynamic principles, such a teaching approach has been more beneficial to students. Students more easily remember the information through this approach. This approach is found to be more effective in conveying certain points than through a direct, unadorned exposition of thermodynamic laws and applications (Bartell, 2001b). These innovative ideas in making science courses more palatable to students normally came from very dedicated and talented instructors, an occurrence that is hard to come by.

Helping students "engage in inquiry" is not a trivial undertaking. It may be more difficult to help students engage in inquiry today than it was in the 1960s. Certainly, students are exposed to a much wider variety of distractions today, with the exponential growth of media culture we experience in present times. Many students undertake chemistry courses for reasons that probably span a much greater range than students of the previous decade. So, how then do we get them engaged? Nash (1966) developed the idea that the most effective method an instructor can use is to be *an example* of what it means to be a scientist. In the presence of students, the instructors should demonstrate commitment and enthusiasm for their subject, ask questions of nature and obtain answers, think logically and with clarity, and respect and encourage their students' potential ability to engage in scientific inquiry.

There are many other approaches to engage students to be active in the learning process (Moore, 1999). Among others are getting students to learn chemistry through group projects, which have been carefully designed to encourage students to explore the designated chemical principles. New Traditions (http://newtraditions.chem.wisc.edu/), for example, has an array of techniques ranging from *ConcepTests* in lectures and *Challenge Problems* for small-group work, through inquiry-based laboratories, to lecture-less courses in which students spend most of their class time working on problems that have been carefully designed to lead them to develop new insights. ChemLinks (http://chemlinks.beloit.edu/) and Modular Chemistry Consortium (http://mc2.cchem.berkerley.edu/) are jointly developing thematic modules in which students learn chemical principles by studying real-world problems, such as how to make a blue LED, strategies to build an automobile air bag. The PLTL Workshop Chemistry project (http://www.sci.ccny.cuny.edu/~chemwksp/) involves students in small-group workshops led by peer instructors who have only recently completed the course of which the workshop is a part of the learning process.

The Molecular Science project (http://server2.nslc.ucla.edu/ms/) applies information technology to allow students to explore databases of real chemical information, and it encourages and evaluates student writings on scientific topics. A number of other institutions are affiliated with these projects as adapt/adopt partners, and as a result of dissemination workshops, many other efforts are under way to focus on student learning rather than faculty teaching (Moore, 1999).

However, all these innovative teaching/learning approaches are very labor intensive. The instructors or the facilitators involved in such teaching approaches will only be able to conduct relatively small classes. If conducted in big groups, students may not be able to stay on track at optimum level, due to limited guidance from the course facilitators.

In developing countries such as Malaysia, where manpower shortage is a stumbling block, particularly in the field of science and technology, local institutions of higher learning are

expected to increase student intake each year. Now the issue has evolved into a bigger and more pressing problem for academic institutions like UNIMAS to explore alternative teaching approaches that provide quality learning opportunities to more students, without compromising the merit of education. One possible approach that has shown potential for success is the delivery of the courses through web-based coaching.

2. Method

2.1. Online learning at UNIMAS

A second-year undergraduate program module in Resource Chemistry, specifically a course in Environmental Chemistry with an enrollment of 30 students, was selected as the first natural science type course to be supported with web-based technology. The course was initially conducted through conventional lecture format, supplemented with typical visual aid and computer-generated instructional materials. The course assessments were normally based on students' in-class participation, and performances in course tasks, and tests. This course was later conducted through an online environment. These two different learning environments were compared for their effectiveness by assessing the following performance indicators:

2.1.1. Student participation

The measuring parameters for this assessment was the frequency of student responses to the course instructor's questions, including the number of questions asked by the students and frequency of peer discussion instances that triggered throughout the course. The course instructor at the end of each class recorded the number of questions asked by students in each class over duration of 10 classes. An average of questions asked per class was calculated. Similarly, the number of students responded to questions posted by the course instructor in each class was recorded and the average for 10 classes was calculated. The level of peer discussion was only monitored through the perception of the instructor in three levels, namely low, moderate and high.

2.1.2. Students' level of commitment to task

The quality of work submitted by the students was used to judge the level of student commitment to tasks assigned to them in the course. The features identified to reveal the nature of their commitment are: the neatness of the submitted report, completeness of the report, the amount of discussion involved among the group members, and the number of references cited in their reports. In this case study, the 30 students were divided into groups of five. The groups were selected at random for every assignment. The group reports for each assignment were evaluated and graded between the grades of A (excellent), C+(average) and F (fail). The number of references cited in each report was recorded and the mean number of references cited was calculated for the duration of the study. A higher number of references cited in a report normally indicates a higher commitment from the student.

2.1.3. Preparation of teaching material by the course instructor

The level of difficulty to prepare for the course lectures was assessed through:

- the prelecture preparations, such as prepping for the technology tools for the learning environment (that is, ensuring the LCD projector, computer and screen are ready for use),
- amount of time spent to prepare lecture materials, and
- the level of presentation success during prescribed lecture sessions.

All these performance indicators are only assessed qualitatively by the course instructor/teacher. The findings in this case study were limited to only the one instructor's perception. The data do not, by all means, reflect the generic teaching practices of all academics at UNIMAS.

2.1.4. Accessibility of the course

Accessibility of the course material to the students is evaluated through the frequency of rescheduled lectures, the number of successful communication between the teacher and the students, and the availability of course materials (lecture notes, assignment submitted, and tutorial solutions) to the students online. On occasions where course instructors are called away from office, the normal scheduled classes will have to be postponed and rescheduled for another time. The rescheduling of classes is considered to be an inefficient practice, thus affecting the normal flow of teaching and learning of a course.

The Environmental Chemistry course was conducted over a period of 16 weeks, with two 1-hour classes per week. The first 5-weeks of the course was conducted in the conventional classroom approach while the second half of the course was conducted online. Comparisons of the two teaching and learning approaches were based on 10 classes completed using each approach.

2.2. Limitations

Although this case study compares both the teaching/learning approaches (the conventional classroom and online approaches), it does not accurately reflect the level of knowledge that students have acquired in the course. Half of the course was completed in the conventional approach before the students embarked into the web-based learning environment, and therefore there was some degree of knowledge acquisition that had already been established. The online learning sessions came in the second half of the course, and the problems in understanding the fundamentals of the course may have been addressed earlier in the semester.

3. Results and discussion

Class participation has always been used to gauge the effectiveness of a particular teaching pedagogy. Based on previous class experiences at UNIMAS, it has been commonly observed that students who are active in class discussion would normally do better than average in the

overall course performance. However, the reverse correlation of the same phenomenon, indicating that the more passive students do badly in the course may not always prove true. These class-performance observations are particularly accurate to describe the majority of students in Malaysia. It is a common classroom culture in Malaysia that students normally are very reluctant to answer questions posed by instructors, and oftentimes they avoid engagements in intellectual discussions.

Table 1 shows an observation of students' participation in the conventional face-to-face classes versus during the online classes.

The mean number of questions asked during a class was 3 for the conventional face-to-face classes and 10 for the online classes, charting and increase of 233% (Table 1). This set of data (Table 1) reveals that, through the supplementary online teaching, more students were beginning to break away from their conventional classroom culture (of being passive participants), and these students showed a level of confidence in asking questions during the scheduled online sessions. It was also revealed that more questions were posted during off-scheduled sessions. A similar trend was observed with respect to answering questions posed by the instructor. In this study (Table 1), for the conventional class only 3 students attempted to answer question in a class whereas there were 21 students involved in the online class. This marks an increase of 600%. More importantly, students engaged in peer discussions on their own accord, using triggers set out by the course instructor, and these discussions were done during nonscheduled class hours. This indicates that these students were participating actively, consequently diminishing the prevalent negative perceptions and practices that favored more passive and individualistic learning strategies, particularly in Malaysian classrooms.

This change in learning strategies may be attributed to the opportunities provided by the web-based instruction, because it allows students to perform discussions by posting their views at any time they wish. Responses to a particular question or issue are easily traceable. This feature also allows the instructor to monitor the progress of student learning, and makes it possible to discern the students' comprehension levels when they deal with specific topics in the course. In this case study, the course instructor was able to send messages to remind and motivate specific students who are not participating as frequently as expected in the web-based learning environment. Such tools are not available to a conventional class, because

Table 1
Comparison of levels of student participation between the conventional lecture class versus the online sessions ($N = 30$ students)

Course: environmental chemistry			
	Classroom (*a*)	Online (*b*)	Difference * % (*c*)
Number of questions asked/class over 10 classes	3	10	+233
Number of students responded/class over 10 classes	3	21	+600
Level of peer discussion over 10 classes	Low	Medium	–
Mean attendance	23	27	+

* Indicates the value of difference between conventional lecture and online sessions in percentages, e.g., $[(b - a)/a] \times 100$—a positive value indicates increase in levels, and a negative value indicates a decrease in the students' level of participation.

typically an instructor will have no means to know or to keep track if students in the courses are coping well with their learning pathways.

Another reason that may have contributed to the increase in student participation was that the online course provided lecture materials and extra-reading resources on the web space, and students could download them at their convenience. Therefore, the students did not have to be as concerned about writing down the notes as the class commences and hence were able to participate in the learning of the subject matter. By doing so students had the ability to understand and recall the course materials better as reflected in their quality of work and their grades.

Table 2 shows the observations on the improved quality of students' group projects or assignments.

The study showed more students from the online class produced good-quality reports as compared to while they were following the conventional class (a 100% increase). Based on the data in Table 2, the improvements presented here may be contributed by the increase in the students' level of enthusiasm about the course, their ability to engage in quality peer discussions while doing group projects, and the quick and more personal access to the course instructor, who guided them through the course of learning. The web-based program was capable of motivating students to do well. The tools allowed more interaction opportunities among peers, and each idea contributed to the project was recorded systematically online, consequently pushing the students to produce their best. The tracing of individual contribution in a group project allows the instructor to award different grades to each member of a group. The common bad learning strategy of "piggyback riding" on other group members can be minimized through the transparency nature of the web-based learning environment. The instructor is actively involved with all the group work phases. Some of the contributions made by the instructor to each group include suggesting some resource materials that the students should refer to, posting trigger questions to expand the scope of project direction—all of which otherwise are overlooked or implausible in the conventional classroom sessions. The main constraint in supervising group projects in the conventional classes is the limited time to meet each group. The availability of most instructors tend to be bound to their normal

Table 2
Comparison of the level of enthusiasm among students between the conventional class and the online class ($N = 6$ groups of five students)

Course: environmental chemistry			
	Classroom (a)	Online (b)	Difference * % (c)
Number of assignments given	4	4	0
Number of poor reports (lower than Grade C)	9	2	− 79
Number of good reports (Grade B+ or better)	8	16	+ 100
Mean of references cited in one report	3	5	+ 67
Total reports received	24	24	0

* Indicates the value of difference between conventional lecture and online sessions in percentages, e.g., $[(b - a)/a] \times 100$—a positive value indicates increase in levels, and a negative value indicates a decrease in the students' level of enthusiasm.

9 to 5 time slots, and the students will carry out their group project outside these hours. With the online learning environment, the instructors now can access the progression of the project at all times, and practically from any location with an Internet connection.

From the instructor's point of view, conducting the course online has several advantages. Table 3 shows some of the experiences encountered by the instructor while teaching the Environmental Science course.

As depicted in Table 3, one of the advantages of online teaching over the conventional classroom lecture is that there is minimal class setting preparation required prior to conducting the class. In the conventional class, the instructor would have to ensure that a computer (ready with the lecture notes) and a data projector are made available. These tools maybe easily available in other technology-savvy countries, but in Malaysia most university lecture theaters are not all equipped with these computing facilities. Therefore, it becomes a chore to assemble the tools at one place at any given time. Many instructors opt to shy away from using computer-based presentations in their lectures, to avoid such tedious work, and most are complacent with using the traditional chalk and board technique. On the other hand, web-based teaching can be done during scheduled computer periods, without the fuss of assembling the projector and computer to the lecture halls. Using the computer class period would mean allowing regular class time to be used for the normal curriculum, such as conducting tutorial classes. Other researchers have observed this advantage also (Moore, 2001).

The major advantage of web-based learning is that the class can be conducted even when the instructor is away from the campus, for instance, when attending external events or conducting field research tasks off campus. The instructor only needs a computer with an Internet facility. In the conventional class, when the instructor is on a traveling assignment away from campus, class sessions would have to inevitably be postponed, thus resulting in backlogged lectures, making it difficult, if not impossible, to reschedule within the predetermined academic semester time frame. The disruption of scheduled classes is rather rampant, especially with instructors who hold senior administrative duties. Students have often complained about such disruptions, and they claimed that the canceling of lectures

Table 3
Qualitative assessment of online teaching by teacher

Course: environmental chemistry		
	Classroom (a)	Online (b)
Prelecture preparation	Simple to tedious	Simple
Preparation of course material	• Need careful preparation and arrangement of course material. • Minimal student input	• Similar to the conventional approach. • Easier for upgrading of course material. • Allow students to input additional reading material for the course.
Delivery of course material	Good	Good
Number of classes rescheduled	5	1
Student counseling	Low and ineffective	Effective
Interruption during the class *	Minimal	Subject to network reliability

* Refers to disturbances that occur during class sessions, i.e., power failures, schedule conflicts, etc.

poses as a distraction to the progression of the course, subsequently making them lose interest in the course. With an online learning environment to supplement the flow of a course, the learning sessions can be rescheduled as and when the need arises.

It is foreseeable that web-based teaching can be used widely, particularly for the distance-learning mode. However, in the context of teaching the course at UNIMAS, it would be unwise to totally indulge in web-based teaching, as we would not be able to meet and get to know the students better. Education does not merely involve the teaching and learning of a subject matter, but it also involves the development of individual personalities and psychosocial factors. Such aspects of human development require physical human interaction. Web-based learning will be a very useful teaching/learning tool, but it could neither completely replace the existing conventional teaching approaches nor become the panacea to existing negative classroom practices.

4. Conclusion

Online learning or web-based learning has the potential to be part of the evolving educational pedagogy today. It has the flexibility to accommodate the needs of individuals, allowing room for innovation to be incorporated into personal learning or teaching styles. Online learning also has demonstrated its capability in incorporating multimedia-teaching techniques, management of group projects, as well as creation of space for peers and teacher/student to build learning communities effectively. These features have made web-based learning practical, and eventually it may become a platform of choice to learn in years to come. The teaching of science courses at UNIMAS has indeed been made easier through the web-based platform. Students were notably more motivated and they exhibited a high level of enthusiasm in learning science subjects, using the innovative tools in web-based technology.

The hype over Web-based learning versus the conventional learning approaches should not mislead course instructors to discard the more conventional approaches. There are some shortfalls in the web-based learning. They are mainly related to the IT infrastructure available to the end-users. Slow transfer of data across the Internet often frustrates users. The reliability of support systems to host and maintain web-based learning environments is imperative. Frequent system breakdowns would drastically affect the flow of the learning process. Until the technology infrastructure of a learning institution is perfected to readily meet the needs of the growing number of students, only then will web-based learning become a more viable option to deliver quality learning.

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