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Use of Multimedia for Experiential Learning in Engineering Technology Labs*

FEI GENG and FAIEZ ALANI
W. Booth School of Engineering Practice & Technology, McMaster University, 1280 Main Street West—ETB 208 Hamilton, ON Canada L8S 0A3. E-mail: alanif@mcmaster.ca

Due to the impact and influence of information technology on the education, computer-assisted language learning is becoming the trend in engineering laboratory based teaching and learning. Furthermore, the interactive computer network allows students to explore the technical information and to conduct the laboratory activities more independently.

In this research, we introduced a multimedia system to the undergraduate lab education in order to transform a traditional lab instruction to the dynamic experiential learning environment. We applied this multimedia method in a number of labs from second-year class to fourth-year class. Then we evaluate the effectiveness of this new lab teaching approach by conducting student survey and lab test. Based on the results of lab test, we will further measure the Course Learning Outcome (CLO) and Program Learning Outcome (PLO) from the classes with or without adopting this method.

Since biotechnology is a discipline of applied science, laboratory application holds high importance in its education. In biotechnology, and other applied science labs, students enhance their learning through seeing, observing, and performing. Our research indicates that this multimedia approach can cultivate the teaching laboratory into more student-centered, active, challenge-based, self-directed learning, and problem based learning environment.

Keywords: mentorship; student mentorship; peer mentorship; cooperative education; experiential learning; co-curricular education; career preparation; professional skills; engineering technology program

1. Introduction

In engineering technology and other scientific-based education, lab-based courses play a crucial role [1, 2]. Engineering technology education requires the understanding of the relationship between theory and practice. In engineering technology laboratories, demonstrations enhance student learning and interest in the subject matter. Laboratory demonstrations allow students to learn the relationship between a scientific principle and its practical use [1, 2].

Even though laboratory experience in student learning is crucial in engineering technology education, it faces some problems. Insufficient laboratory conditions and expensive equipment result in overcrowded groups that lead to lack of ability to see and observe the demonstrations. Since laboratory equipment is very costly, only a limited amount of laboratory equipment is available and accessible [3]. Many students have to share equipment in small laboratories that limits the laboratory experience due to overcrowding and creates an inability to view the demonstrations. Even in cases where equipment is sufficient, students usually end up becoming spectators as instructors conduct experiments, due to large groups and overcrowding [3, 4]. Considering the limitations that constrain lab experience, investigating and implementing alternatives to enhance pedagogical laboratory based learning becomes inevitable [3, 4].

Multimedia laboratory is a modernized teaching laboratory featuring the latest multimedia technology that is hardware with software, including tools and applications. The advantage of using a multimedia method is that lab protocols are explained step-by-step and in real time during labs [5, 6]. This helps students to work independently allowing the instructor more time for interaction with the students [7, 8]. The use of images and demonstrations are important in Biotech lab teaching because it improves biosafety as this lab is the only undergraduate lab designated biosafety level 2 in the Faculty of Engineering. Multimedia also allows students to learn new and complex protocols and skills [8]. Another advantage of this method is efficient use of single and expensive lab instruments such as the Bioreactor, the Biochemical Analyzer, High Performance Liquid Chromatography (HPLC) and the Fluorescent Microscope. By transferring their images and results from different lab workstations to a monitor, students can share and compare the results from each workstation which will help in understanding techniques, strengthen lab discussions, and improve the writing of final lab reports [9]. Many biotechnology and molecular biology reagent suppliers and diagnostic companies have their kits, techniques and protocols in multimedia formats and online. For Bachelor of Technology students, exposure to this method of conducting labs is integral to their preparation for future work. With this multimedia use in labs, each

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student group can watch, directly from suppliers, new and complicated lab protocols and perform protocols efficiently in the lab with the lab instructor as facilitator rather than demonstrator [10–11]. Students' response to the new learning technique will be discussed.

In Bachelor of technology students are exposed to intensive lab hours to gain hand—on technical skills. Multimedia is relatively new teaching method for labs. It was suggested by many authors that multimedia is effective tool in lab teaching and learning. Patterson [12] found multimedia laboratory manual is effective method to teach in mass and energy balance lab and suggested must be used in all laboratory courses. Heitman [13] found including multimedia in biology lab report, they concluded that improve lab report and safe time for lab report grading.

Multimedia learning modules (MLMs) in teaching human anatomy was described by Van et al. [14] Each MLM consists of two complementary sub elements: a multimedia theoretical lecture and a three-dimensional interactive laboratory. Alani, and Geng & Alani [15, 16] suggested reinvent enhanced lab teaching and learning use multimedia in lab teaching enhance teaching and learning and save time and money in lab teaching and learning. We have designed multimedia system for teaching biotechnology labs and reporting the role of this system in enhancing student experiential learning.

The usage of the multimedia system will be blended with the traditional teaching; thus, this lab teaching technology will greatly enhance biotechnology and bioengineering education at a variety of levels.

2. Methodology

2.1 Biotech lab description

This state-of-the-art biosafety level 2 facility is home to a solid and aqueous systems Bioreactors which cultivates cells to produce antibiotics, vaccines, enzymes and organic acids. In addition, this lab houses a biochemical analyser and biosafety cabinet, as well as fluorescent and inverted microscopes to view cells and cell components, DNA, and protein molecules that have been stained with fluorescents.

The lab also houses an advanced Gel Documentation System for image capturing, thermal cycler for using real-time PCR (Polymerase Chain Reaction) to replicate DNA, electroporator, ultrafiltration system and High Performance Liquid Chromatography (HPLC) system for the analysis of protein molecules, and a solid state bioreactor to cultivate microorganisms on a packed bed.

2.2 Lab setup

In the Biotechnology stream at School of Engineering Practice and Technology (SEPT), lab components were applied to biotechnology students starting from the first year. General biology (1st year), Microbiology (2nd year), Biotechnology I (2nd year), Genomics and Proteomics (4th year) were taught with a lab component in each course. In this research we chose ETB-311 biotech lab as the lab location as it is equipped with most advanced multimedia system and data sharing system for all the lab equipment. In this lab, students are able to access the lab manual, materials and educational videos through the user portal. All the digital information displayed on the instrument (e.g., microscope) can be duplicated on all the monitors by each lab bench. This type of feature allows students to have real-time discussion on their lab results, which enables them to perform trouble shooting and to modify their lab procedures accordingly.

2.3 The design of multimedia-assisted lab teaching environment (MALTE)

MALTE is an integrated software environment that covers three activities of teaching and learning in the lab with the use of multimedia.

(a) Presentation: Delivery of teaching and assessment material by a presenter, who navigates through the presentation, narrates the slides and answers students' questions. In a presentation, a teacher has an opportunity to illustrate lecture concepts with the material drawn from case studies or the material that is also available for students' self-directed work.
(b) Video show: This includes creation of multimedia teaching components by writing, drawing, composing and reusing those components in a video show. In the process, instructors develop a large database of case studies, together with problem descriptions, their fully developed solutions, and design patterns that can guide developers in arriving at a solution.
(c) Webcam demonstration: Reception involves active learning and evaluation of acquired knowledge by students in remote locations. The learner listens to the lecture and views the slides, asks questions, browses through the material independently of the presenter, or undertakes drills, quizzes and other types of assessments

2.4 The design of the study

This study on the effectiveness of using multimedia system in the laboratory teaching was conducted through an anonymous student survey. The study

participants comprise of the second year and the fourth year students in Biotechnology Stream in School of Engineering Practice and Technology at McMaster University. They were asked to complete an anonymous paper-based survey which took 10 to 15 minutes to complete. In total, 28 students in the second year and 33 students in the fourth year of Biotechnology Stream at McMaster University voluntarily participated in this study.

The questions asked about their experience with multimedia usage in the laboratory teaching and to rate the effectiveness of the multimedia component from a variety of aspects including (1) Understanding the fundaments of the technology; (2) Familiarity with the workflow of the experimental procedures; Identifying the step(s) that could cause error in the lab; (3) Managing the materials or reagents that are required in the lab; (4) Being more creative in the lab environment; (5) Improving the successful rate of the labs.

2.5 The evaluation of the study

To evaluate the effectiveness of the multimedia system in the laboratory teaching, we analyzed the student survey results using Office Excel software and generated column graphs based on the survey answers of 2nd year and 4th year students.

3. Results

As shown in Fig. 1, we have established multimedia based biotechnology labs which integrated the internet into the lab teaching.

At the beginning of the survey, we seek to find out the course(s) that has used the multimedia system during the laboratory teaching. That being mentioned previously, General Biology, Microbiology, Biotechnology I and Genomics & Proteomics are the courses offered to the students with lab components. As shown in Fig. 2, most of the 2nd year students (85%) and 4th year students (90%) respectively chose Microbiology and Genomics & Proteomics as the course that applies multimedia system in the lab teaching.

Since biotechnology courses including Microbiology and Genomics & Proteomics were taught by different instructors, the frequency, duration and formatting of multimedia usage can play a big factor in the effectiveness of MALTE. Thus, the second part of the survey focuses on these technical parameters during the multimedia usage and the statistics of the three aspects were shown in Fig. 3–5. Most of 2nd year and 4th year students agreed that the multimedia system have been used for 5 or more times with 10–15 minutes each time.

In terms of the formatting, most of the students mentioned that slide presentation and video show are the two major applications of the multimedia system in the lab teaching activities while webcam demonstration seems to be a bit less used.

The third part of the survey focuses upon the effectiveness study of the MALTE (Figs. 6–10). First of all, in terms of managing the materials or reagents are required in the lab, most of the 2nd year students seem to consider that the usage of multimedia system is very little helpful (40%) or moderately helpful (30%). In comparison, 35% of the fourth year students consider it as moderately helpful (30%) and the rest of the students chose either very little helpful (20%) or much helpful (25%) (Fig. 6). This indicates the usefulness of multimedia system in the management of materials and reagents still remain to be improved.

While over 35% of the students both from the 2nd year and 4th year consider the usage of multimedia system is much helpful in identifying the steps that could error in the lab (Fig. 7). In great consistency, the majority of the students from both the levels agree that the usage of multimedia system improve the successful rate of labs (Fig. 7).

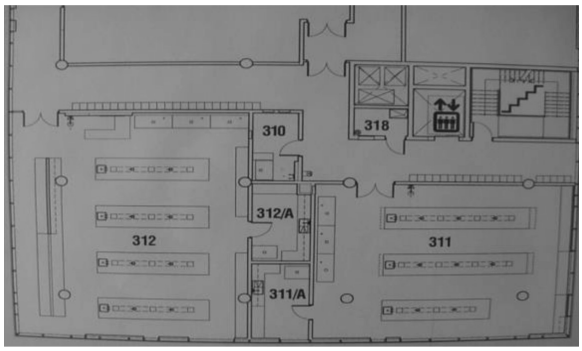

Fig. 1. Biotechnology lab floor plan sketch. Three monitors on each lab bench (rectangular shape) are wirelessly connected with computers inside biotechnology labs (room #311 and room #312).

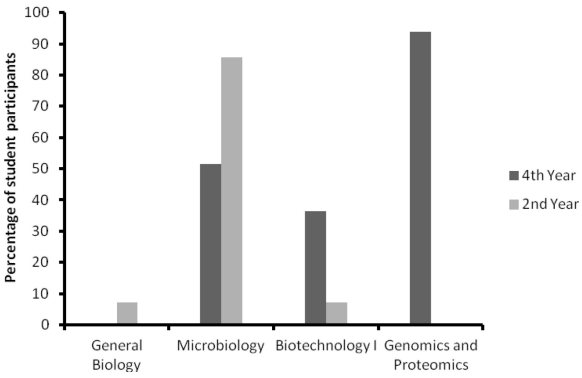

Fig. 2. The courses in Biotechnology stream that utilized multimedia system in the lab teaching. We have conducted an anonymous survey and calculated the percentage of students who experienced the usage of multimedia based teaching in 2nd year and 4th year courses in biotechnology stream.

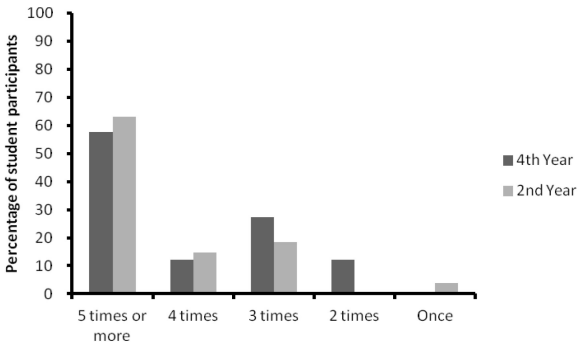

Fig. 3. The frequency (per course) of multimedia system usage. We have conducted an anonymous survey and calculated the percentage of students who provided the frequency of multimedia usage per course in 2nd year and 4th year courses in biotechnology stream. (all the courses are of the same length).

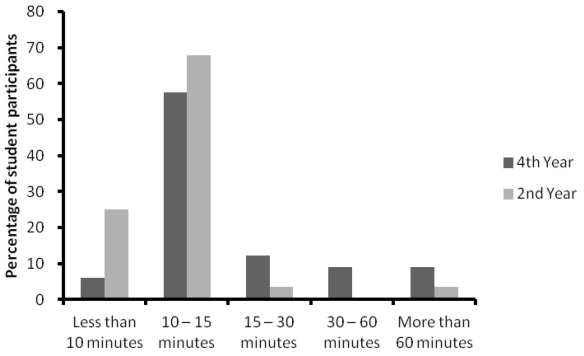

Fig. 4. The duration of multimedia system usage. In the anonymous survey, we calculated the percentage of students who provided the duration of multimedia usage in 2nd year and 4th year courses in biotechnology stream.

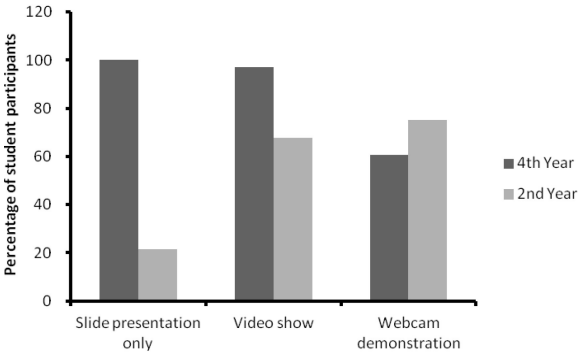

Fig. 5. The formatting of multimedia system usage. In the anonymous survey we conducted, we calculated the percentage of students who provided the duration of multimedia usage in 2nd year and 4th year courses in biotechnology stream.

As a critical goal of lab education, creativity has always been the focus of experiential teaching and learning which targets the experimental design and troubleshooting. Over 35% of the 2nd year students and around 33% of the 4th years consider the multimedia usage as moderately helpful or completely helpful (Fig. 9). In parallel to the creativity, familiarity effect was also evaluated in Fig. 10 and it seems that almost all the students in the both the

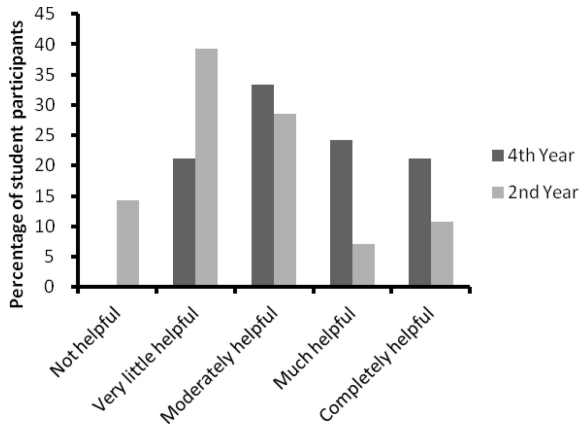

Fig. 6. The effectiveness of multimedia system in managing the materials or reagents that are required in the lab. In the anonymous survey, we calculated the percentage of students who comment on the effectiveness of multimedia usage in 2nd year and 4th year courses for the lab materials mangement.

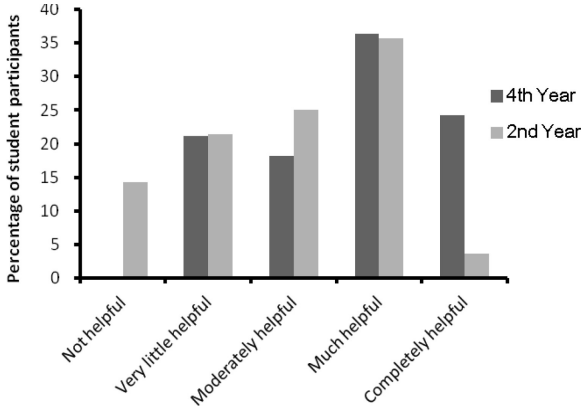

Fig. 7. The effectiveness of multimedia system in identifying the step(s) that can cause error in the lab. In the anonymous survey, we calculated the percentage of students who comment on the effectiveness of multimedia usage in 2nd year and 4th year courses for the idenfication of lab errors.

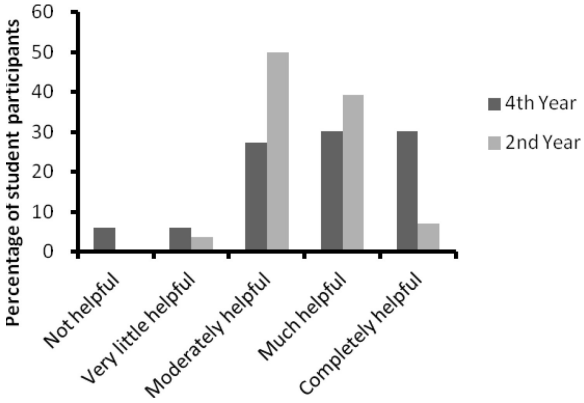

Fig. 8. The effectiveness of multimedia system in improving the successful rate of the labs. In the anonymous survey, we calculated the percentage of students who comment on the effectiveness of multimedia usage in 2nd year and 4th year courses for the improvement of lab successful rate.

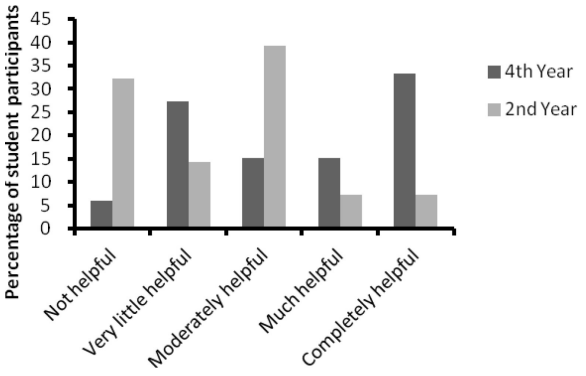

Fig. 9. The effectiveness of multimedia system in being more creative in the lab envionment. In the anonymous survey, we calculated the percentage of students who comment on the effectiveness of multimedia usage in 2nd year and 4th year courses for the improvement of lab creativity (in experimental design and troubleshooting).

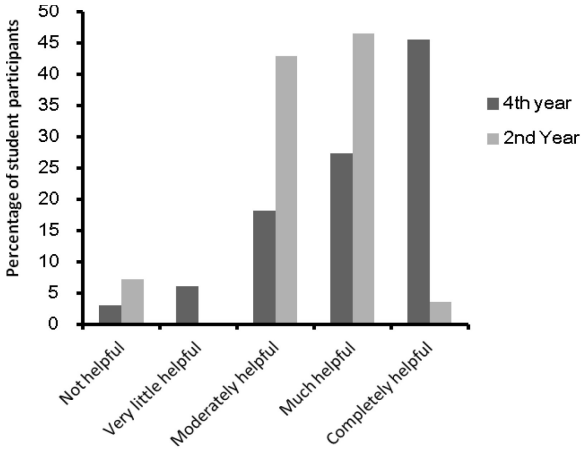

Fig. 10. The effectiveness of multimedia system in familiarity with the workflow of the experimental procedures. In the anonymous survey, we calculated the percentage of students who comment on the effectiveness of multimedia usage in 2nd year and 4th year courses in improvement of lab familiarity.

Table 1. Lab learning outcome assessment of Microbiology (2nd year) by lab report. Based on the seven learning outcomes (biosafety, sterilization, isolation, microscopy, identification, enumeration and sample analysis), we came up with the lab mark for each learning outcome in the Microbiology lab reports.

Lab learning outcome	0–49	50–59	60–79	80–89	90–100
1. Biosafety	1	0	2	08	27
2. Sterilization	0	0	0	10	28
3. Isolation	03	0	03	11	21
4. Microscopy	04	0	04	12	18
5. Identification	07	02	14	12	03
6. Enumeration	0	02	06	13	17
7. Sample analysis	04	04	09	14	07

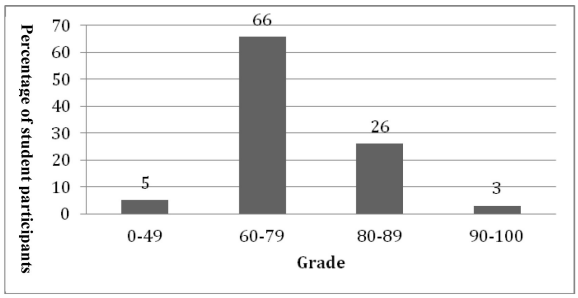

Fig. 11. Lab learning outcome assessment of Microbiology by lab test. In order to assess the effectiveness of lab teaching, we analyzed the grade distribution (% percentage) of final lab test in 2nd year course Microbiology.

levels agree that the multimedia system can make them familiar with the workflow of experimental procedures.

Since the data in Figs. 2–10 are derived from the students' perspective which can be biased by the academic performance of the students themselves, in order to validate the survey data, we conducted a lab outcome assessment of microbiology (2nd year) and Genomics &Proteomics (4th year) in lab report (Tables 1–2), and lab test (Figs. 11–12) respectively. A normal distribution was observed in the lab test mark (Figs. 11–12) and many of the learning outcomes from lab report mark (Tables 1–2) in both courses. Together with the student survey results,

Table 2. Lab learning outcome assessment of Genomics and Proteomics (4th year) by lab reports. Based on the seven learning outcomes (biosafety, HPLC, Fraction Collector, DNA microarray, 2D gel electrophoresis, In-gel trypsin digestion), we came up with the lab mark for each learning outcome in the lab reports of Genomics and Proteomics.

Lab learning outcome	0–49	50–59	60–79	80–89	90–100
1. Biosafety	0	01	05	08	19
2. HPLC	0	0	15	15	03
3. Fraction Collector	0	03	13	16	01
4. DNA microarray	0	06	18	06	03
5. 2D gel electrophoresis	0	05	15	12	01
6. In-gel trypsin digestion	01	02	06	11	03

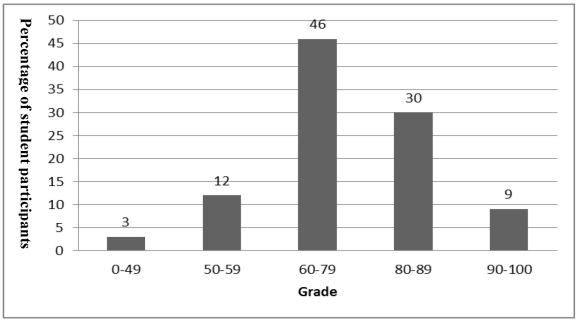

Fig. 12. Lab learning outcome assessment of Genomics and Proteomics by final lab test. . In order to assess the effectiveness of lab teaching, we analyzed the grade distribution (% percentage) of final lab test in 4th year course Genomics and Proteomics.

this data (Figs. 11–12 and Tables 1–2) corroborated our previous findings that the integration of multimedia system has effectively facilitated the lab teaching and achieved the desired learning outcomes without creating the noticeable bias in the student population.

4. Discussions

In the past, it has been indicated that there is a need for courses that are professionally designed and evaluated, which adopt effective learning strategies and encourage a self-directed learning [6, 13]. When it comes to the area of lab teaching, an effective learning environment becomes more critical in order to improve the engagement and deliver hands-on education. We address these issues by teaching with the use of interactive multimedia learning environment. In this paper we described the usage of multimedia system from the student's perspective and we seek to understand its effectiveness in facilitating traditional lab teaching with the use of lectures, tutorials and practical sessions.

First of all, on the basis of a standard biotechnology lab (Fig. 1) we incorporated the components of multimedia system (computers, lab bench monitors, wireless connection with all the equipment) and generated the Multimedia-Assisted Lab Teaching Environment. Then in the student survey we studied the parameters that are associated with the usage of multimedia system in the second year and fourth year courses including frequency, duration, formatting (Figs. 2–5). Our data demonstrate that the multimedia system has been utilized similarly across the board although the formatting might be a bit different from 2nd year to 4th year courses.

Although the multimedia system has been widely applied in many aspects of teaching activities, its effectiveness in each aspect has not been well studied. Therefore, in this study we have investigated the performance of multimedia system in the areas of lab teaching and the survey results showed that the multimedia system improved the aspects of identifying the step that can cause error in the lab (Fig. 7), improving the successful rate of the labs (Fig. 8), being more creative in the lab environment (Fig. 9), in familiarity with the workflow of the experimental procedures (Fig. 10). In the meantime, it is also understandable it does not facilitate the management of the materials or reagents that are required in the lab (Fig. 6).

Other than the information (Figs. 2–10) derived from the student perspective, we also conducted the learning outcome assessments (Figs. 11–12) in the 2nd year and 4th year courses in order to validate the survey results. Our results showed that comprehensive learning outcomes have been achieved at normal distribution (peak at grade 60–79) in both the courses (Tables 1–2 and Figs. 11–12). This further supported our hypothesis that the multimedia system is improving the teaching of the whole student population on a non-biased basis.

Based on the comments in the student survey, we also summarized the benefits from using multimedia system in the lab teaching: (1) Effectiveness: students can work on case studies in their own time and at their own pace to suit their individual needs. (2) Flexibility: lecture slides, video show and webcam demonstration are available on demand, which provides wider choices of learning paths and individualizes instruction.

In this way students continue designing the solution under the guidance of the tool constructing sequence, collaboration, class and state diagrams. The system provides the students with some problem descriptions, engages them in snapshot quizzes which are an integral part of the case study, guides them towards high quality problem solution, explains its design decisions, and supplies the students with knowledge on good and bad design choices.

5. Conclusions

Through the use of multimedia system students develop good understanding of an object-oriented design process, the relationship between individual stages of the process, and most importantly they learn to judge the value of alternative ways to solving a problem in their future workplace. Our future plan involves the in-depth investigation the potential applications of this multimedia system in teaching and learning such as "the multimedia lab report", in which case students provide verbal presentation on the lab results. Our main strategy was the use of a problem-solving approach.

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Fei Geng graduated from Jining Medical College in China in 2001. In 2004, Dr. Geng received his master's degree in Biochemistry at Fudan University and successfully discovered the prognostic biomarker for lung cancer patients based upon the results from the biochemical studies as well as the statistical analysis of clinical studies. In 2004, Dr. Geng came to Canada and started his PhD studies on the molecular mechanisms of breast cancer cell death under the supervision of Dr. David Andrews and Dr. Brian Leber in Department of Biochemistry and Biomedical Sciences at McMaster University. During his PhD studies, Dr. Geng discovered a novel cancer cell death signaling pathway, which could be utilized to treat the recurrent breast cancer that is resistant to chemotherapy. In May 2013, Dr. Geng joined the Bachelor of Technology Program as Assistant Professor.

Faiez Alani is Associate professor at School of Engineering Practice and Technology, McMaster University; He obtained his PhD and M.SC from University of Strathclyde. His research Interests & Expertise are in Case study based learning and experiential learning, Microbial Biotechnology, Biochemical Engineering, and Nanobiotechnology. Faiez is member of Editorial Advisory Board of Journal of Science and Technology Policy Management and International Journal of Engineering Education, member of Canadian Engineering Education Association, and Society for Industrial Microbiology and Biotechnology.