Industrial hygiene laboratory for distance education. Part 2: Course evaluation

A college-level laboratory course titled "Industrial Hygiene Virtual Laboratory" (IHVL) was created in CD-ROM format. In the beta version tested and reported here, the laboratory contained 11 modules, including calibrations, particulate sampling, sampling for gases and vapors, ventilation and indoor air quality, noise, bioaerosols, and thermal stressors. The efficacy of this course was classroom tested among 10 upperclassmen enrolled in a course on the topical material taught by the CD-ROM. Students were divided into two matched groups, which alternately performed laboratory sessions either on the CD-ROM or in the traditional college teaching laboratory. Differences in average scores between the groups were not statistically different ($p = 0.05$). Pedagogical conclusions are that the electronic laboratory sessions were not better at teaching the subject matter, but that the CD-ROM laboratory is at least as effective as attendance in traditional teaching laboratory. Implications for teaching this or other traditionally laboratory-based courses are discussed.

By Timothy J. Ryan

INTRODUCTION

This paper describes the efficacy testing of a college-level laboratory course in the applied sciences. Titled Industrial Hygiene Virtual Laboratory (IHVL), development of the CD-ROM-based course has been fully described in a companion manuscript.[1] As evaluated here, the autonomously performed lab sessions were used in lieu of a weekly, 1 credit-hour laboratory meeting. The IHVL was utilized in conjunction with a 4 credit-hour weekly classroom lecture. The level and material covered was an upperclassman course described as "IH Sampling and Analysis." The objectives of the course are to teach the fundamentals of industrial hygiene (IH) media selection, quantitative and qualitative analysis methods, instrument principles, and equipment limitations.

Attempts at spanning the "laboratory hurdle" in distance education have been made in a number of basic science and engineering topics, including entomology, geology, physics and chemistry.[1] Either to facilitate more convenient continuing professional education or to augment traditional on-campus programs, such applications are increasingly making their way into mainstream coursework requirements. Benefits and shortfalls of multimedia approaches have been well described,[2–6] but rigorous testing of their performance and ability to teach students is essential absent in the literature. This paper describes the results of such testing for the IHVL.

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METHODS

The IHVL was classroom tested among 10 upperclassmen enrolled in a university-approved class on the topical material taught by the CD-ROM. Students were divided into two groups (A or B) of five students each (Table 1). To the extent possible with the small class size, groups were matched by gender and academic achievement level, as indicated by the cumulative grade point average (GPA). Academic matching was hindered by a single student ("JW") with an unusually high GPA of 3.9. It is notable that this student was the only Student-Older-Than-Average (SOTA) in the class. Both groups consisted of three males and two females, with a combined previous quarter average GPA of 2.9. Group members alternately performed laboratory sessions either using the CD-ROM or live, in the college teaching laboratory, according to the instructor-assigned laboratory schedule shown in Table 1. To keep laboratory sessions synchronized with classroom lectures, each week both groups worked on the same laboratory topic whether on CD or in the traditional laboratory.

Based on prior experience in teaching the laboratory material, it was believed that some of the IH laboratory topics were more difficult to grasp than others. For this reason the investigator did not randomly assign IHVL modules to the two groups. Rather, both groups were exclusively assigned several conceptually difficult and several conceptually easy topics. Group A was assigned the topics of Calibrations, Gas and Vapor Sampling, Noise and Thermal Stressors, of which the Gas and Vapor and Noise modules were

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Table 1. Matched Groups[a]

	GPA	Male:Female	IHVL Modules Assigned
Group A	3.1	3:2	Calibrations, Gas and Vapor, Noise, Thermal Stress
Group B	2.6	3:2	Particulates, Ventilation & IAQ[b], Bioaerosols, Thermal Stress
Average	2.9		

[a] Grade point averages, sex, and assignments.
[b] Ventilation & IAQ are separate IHVL modules, both of which were required to be completed in a single week in order to maintain parity with the traditional laboratory assignment.

historically more difficult. Group B was assigned the topics of Particulates, Ventilation & IAQ, Bioaerosols, and Thermal Stressors, with Particulates and Ventilation & IAQ considered the more challenging of the four. As a check for instructor grading bias, all students performed one identical session (i.e., Real-Time Instruments) as a combined group in the traditional laboratory. As a second check on potential grading bias, all students were also required to perform a single IHVL laboratory (i.e., Thermal Stress) exclusively via the CD-ROM.

Testing of the IHVL took place throughout a single academic quarter lasting 10 weeks. During this period, there was one shared laboratory session on Sampling Statistics which was not graded as a laboratory. One laboratory day was lost as an official holiday. Thus, a total of eight traditional laboratory sessions are the basis for comparison in this study. On session days when a particular group was assigned the laboratory topic on CD-ROM, those students were not required to report to the teaching laboratory. Although they were given the option of observing the traditional laboratory sessions for those modules assigned to them on the CD-ROM, no students elected to attend live lab sessions when they were assigned that topic on the IHVL.

All laboratory sessions, whether IHVL or traditional, required the student to submit a laboratory write-up to the instructor. Regardless of how a given laboratory topic was covered, written answers to specific laboratory questions were also expected. These questions and answers were printed out from the IHVL Lab Notebook section, or were generated for traditional laboratory sessions using a word processing program of the student's choice. IHVL reports had a standard format and appearance, making them distinctive to the instructor at grading. All laboratory reports were required to be completed and turned in to the instructor within seven days of the preceding laboratory session. All laboratory reports were graded on a 10-point scale, constituting 40% of the student's class grade. (The other 60% of the student's grade was based on a mid-term and final exam administered in the classroom setting.)

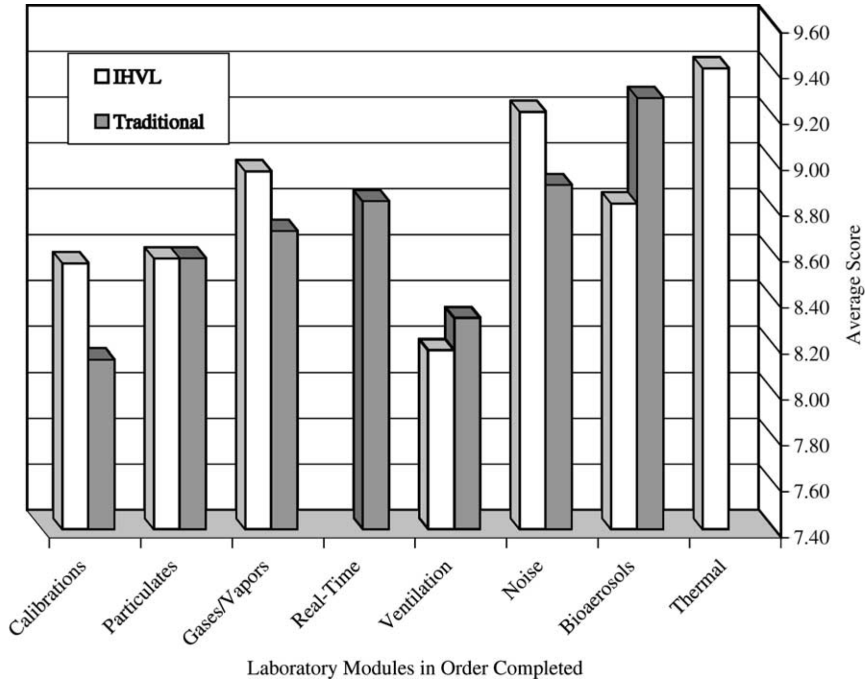

Figure 1. IHVL versus traditional laboratory scores.

RESULTS

Differences between average IHVL and traditional laboratory scores were not statistically significant ($p = 0.05$; two-tailed t-test). Only in the case of the Bioaerosols module did differences approach significance ($p = 0.07$), with the average traditional session scores exceeding the IHVL average by 0.5 point. It should be noted that student "JW" performed the Bioaerosol laboratory in the traditional session and his superior grade was most likely the cause for the difference observed. The average score from the traditionally completed calibrations module was obviously lower than the IHVL (Figure 1). That session was the first of the eight and it appeared to the instructor that the students' lack of familiarity with the new laboratory surroundings may have played a role in this result.

When average scores were compared by groups, Group A average scores were significantly better than Group B ($p = 0.051$; two-tailed t-test). Significance was lost, however, when the scores for "JW" were removed from the comparison. Figure 2 depicts group average scores with "JW" values removed. It must be reiterated that the number of study subjects was too small

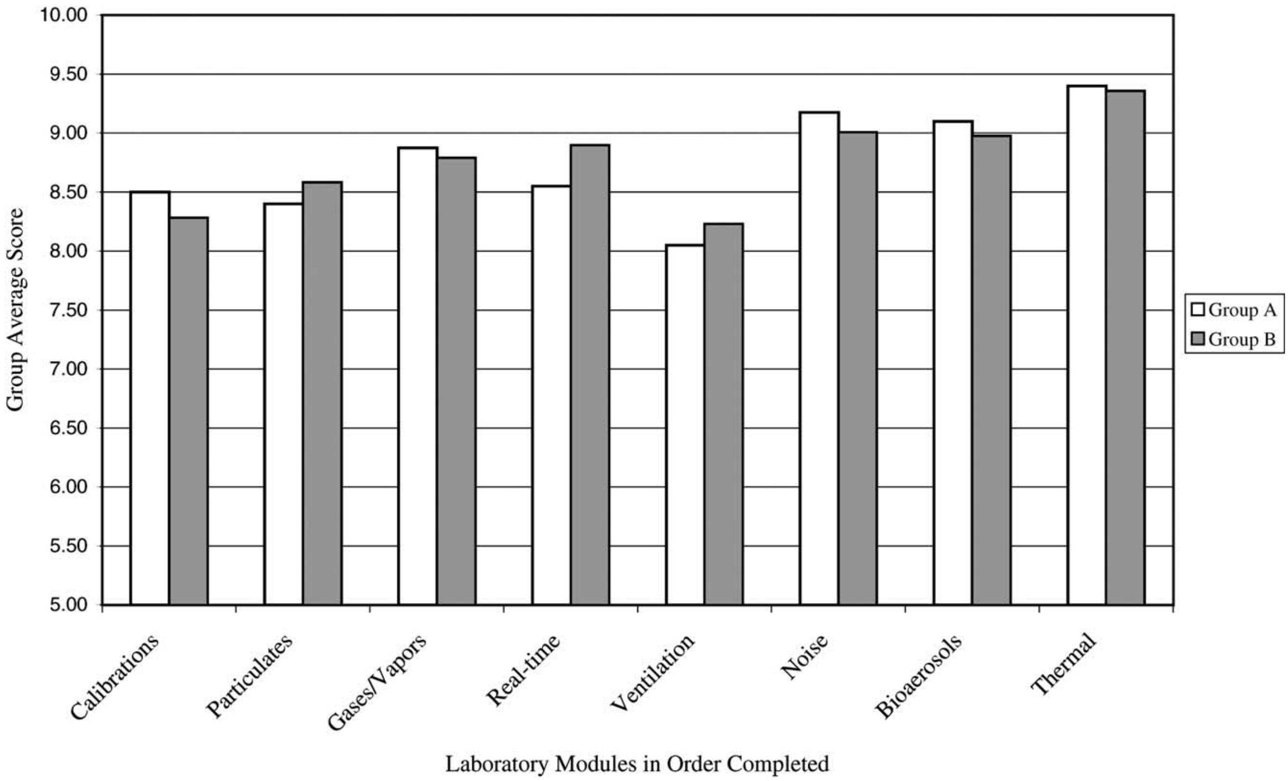

Figure 2. Group averages. Results exclude student "JW."

to assess the magnitude of group differences with a high degree of precision.

Both Figures 1 and 2 demonstrate a rise in all scores as the academic quarter progressed. Possible explanations for this finding are that students were becoming more proficient at preparing laboratory reports and answering questions, that the instructor's grading procedures were becoming more lenient as he came to know the students, or a combination of both reasons. A notable exception to the trend was the Ventilation & IAQ laboratory, in which all scores were almost a full point lower. This result could be used to argue against the more lenient grading explanation. Whatever the cause for the trend, both figures demonstrate that it was consistent between groups and by laboratory type.

The Real-Time Instruments lesson was completed by all students in the traditional laboratory setting. Average group scores were similar (8.7 and 8.9 for Group A and B, respectively). For the Thermal Stressors module, completed entirely on CD-ROM by all students, both groups of students performed equally well (9.5 and 9.3 for Group A and B, respectively). This may have been due to pre-existing familiarity with the concepts in the module (e.g., temperature measurement, wind-chill, and relative humidity), or to the fact the laboratory was the last completed for the course. In such case, student scores partially reflect their proficiency at completing laboratory reports. The closeness of the two group scores indicates that they were reasonably matched academically.

DISCUSSION AND CONCLUSIONS

The implications of teaching this or other historically laboratory-based courses in an autonomous, virtual mode are encouraging. Test scores demonstrate that the IHVL laboratory sessions were not more effective at teaching the subject matter than were sessions attended in-person. However, these results could be used to argue that the CD-ROM laboratory is at least as effective as the traditional teaching lab approach (when used in conjunction with a companion classroom lecture course). Insofar as computer algorithms can be constructed, appropriately animated, and fitted with a realistic degree of uncertainty in order to imitate a real experimental setting, it is reasonable to conclude that other basic science laboratory courses can also effectively be taught employing a virtual laboratory setting. If the experiences of the medical and allied health sciences are useful indicators (the case could be made they are, since such education entails life or death outcomes) then virtual experiential learning in safety sciences should be feasible.[7] Early work in the obviously hands-on field of hazardous materials management has already been attempted, yielding mixed results.[8]

An obvious bias in this study is that it was not possible to use a double-blind experimental design when grading laboratories. This was due to limited staffing for the IH Sampling and Analysis course, and the distinct appearance of the IHVL generated laboratory reports. The small number of students included in this trial is a second limitation to the precision of the results.

Still, the 10 students studied do provide a reasonable basis for an initial comparison even if not statistically powerful. Additional studies with larger groups (e.g., paired classes with 35 or more students each), or longitudinal studies involving successive classes, could be conducted to better assess the validity of these findings.

The difficulty of the materials differed moderately by presentation method. This sometimes resulted in different work products to grade depending on whether the student had completed the material traditionally or with the CD-ROM. For example, in the laboratory on Particulates, it was necessary to adjust the traditional laboratory scores upwards by 4 points to maintain parity with IHVL results. This was because the CD-ROM session did not include four conceptually difficult questions included in the traditional laboratory question set. Those four questions were universally missed by the students to which they were assigned. For the same reason, scores on the laboratory topic of Ventilation & IAQ were also adjusted upwards by one point for the group performing that laboratory in the traditional laboratory setting.

Benefits of non-laboratory autonomous education opportunities to safety and health professionals have been described elsewhere.[2,9] The advantages of a validated virtual laboratory course in IH or other sciences are numerous. First and foremost among these is that the virtual laboratory is safer than the sometimes poorly supervised, loosely monitored undergraduate teaching laboratory. To hosting institutions, the minimization if not outright elimination of certain highly hazardous manipulations in favor of virtual exercise counterparts should be attractive. Also of importance to the institution is the lack of a need for expensive teaching laboratory space or equipment, increasingly regulated hazardous materials procurement, and the disposal of laboratory wastes. Where a virtual laboratory experience can be demonstrated to be at least as effective as an in-person session, the modest development costs of such virtual teaching modules should be given careful consideration.

In 1993, the American Academy for the Advancement of Science advanced a science teaching policy away from a predominantly didactic model (i.e., lectures imparting basic facts) toward a learner-centered model.[10] Originally impossible to deliver in the dispersed environment of distance learning, laboratory focused learner-centered experiences are increasing feasible through the autonomy granted by the CD-ROM format. In this regard the IHVL is currently under consideration as an autonomous education tool within the host institution. If implemented as such it will be delivered as teaching alternative integrated into conventional distance education course materials (e.g., a self-paced syllabus, reading and examination schedule). At such time as a stand-alone distance education course is created, results from this study can be used as an indication of the validity of such an approach, and as the basis for further testing of the efficiency of virtual laboratories in general.

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