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The Impact of Blended Learning on LabVIEW Certification Test Scores—A Case Study*

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This paper introduces an efficient blended learning approach to teaching LabVIEW-based graphical programming and examines the impact of the proposed approach on LabVIEW certification test scores. A traditional course was blended with e-learning technology to boost the programming skills of students and to better teach advanced topics. The need to complete student-designed projects and a certification exam encouraged the students to use the e-learning system outside of class, in addition to their work in regular classroom time. Individual data analysis and student survey results showed that e-learning was mainly used as a tool to help prepare for the certification test. In our case study, students who used the e-learning system achieved certification test results almost 40% higher than those who only had face-to-face learning experiences.

Keywords: engineering education; blended learning; e-learning; graphical programming; LabVIEW; certification test

1. Introduction

The learning environment as we know it has changed considerably in recent years. The days are gone when the only learning option was a face-to-face classroom experience, where the teacher came in and delivered a lesson or lecture on the topic of the day. Today's 'classrooms' are often virtual, and education can be traditional, blended, or fully online. In order to teach effectively in these new environments, educators have adopted a variety of pedagogical strategies and innovative technologies to enable better learning [1–3].

In fact, no single learning environment will sufficiently meet all learning needs, and many educators employ various learning technologies alongside traditional methods in a blended learning program, which combines e-learning and traditional learning methods. Like many advances in educational practice, blended learning has been defined and implemented in multiple ways; as more and more schools are coming to use blended models, many different meanings have evolved [4–6].

Blended learning is gaining particular popularity in higher education. The goal of a blended approach is to join the best elements of face-to-face and online instruction. In-class time can be used to engage students in complex interactive experiences; meanwhile, online activities provide students with multimedia-rich content at any time of day and anywhere they have Internet access, including computer labs, coffee-shops, or students' homes. This allows for more flexible study [7, 8].

However, the development of optimal blended learning environments depends on our understanding of how e-learning is best adapted into the curriculum and how it actually used by students [9–11]. The sharing of best practices and effective usages thus constitutes an indispensible contribution to the goal of optimising blended education, helping teachers to decide how technology will be used in the classroom and understand how it will affect learning. Several studies have found that e-learning is as effective as or better than the traditional university class structure [12–15]. However, results can vary according to content, the digital delivery and/or e-learning incorporation methods, and student motivation. This complex variety of factors affecting blended learning is best explored through case studies, which can offer insights thereby into the real-world applications of blended learning.

This paper offers one such case study. It outlines a method for blended learning and investigates the impact of its implementation on a certification test conducted in a LabVIEW-based graphical programming course for engineering students.

The paper is organized as follows. The outline of the graphical programming course is introduced in Section 2, and the experimental results used to evaluate the impact of blended learning are discussed in Section 3. Finally, concluding remarks and directions for future research are proposed in Section 4.

2. LabVIEW course overview

LabVIEW-based graphical programming developed by National Instruments (NI) is most frequently used in engineering systems designs. Engineers and programmers often use graphical programs to translate information about physical

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events, such as vibrations and temperatures, into visual readouts. LabVIEW is one such graphical programming tool; it is tightly integrated with various measurement hardware for data acquisition, analysis, and presentation. The productive development environment provided by LabVIEW allows users in the science and engineering fields to create custom applications that interact with real-world data or signals form sensor-based systems. LabVIEW itself is a software development environment containing numerous components, several of which are required for any type of test, measurement, or control application [16–18].

Because graphical programming does not require users to have a strong background in text-based programming, it can be especially useful in engineering education. Instead of having to translate high-level design elements into complex text strings, engineering students can create programs using function blocks, wires, and loops that look similar to their whiteboard drawings of an application. LabVIEW thus provides a complete application development environment that makes the development process faster and easier. Fig. 1 shows a typical LabVIEW graphical programming environment.

Today, educators use LabVIEW for teaching engineering concepts, facilitating students' design projects, and training students in researching advanced topics. LabVIEW allows hands-on investigation of sensor-based systems by acquiring a signal, performing analysis, and thus visualising the data, which is a very important process in engineering education.

2.1 Traditional face-to-face learning

For the last several years, a LabVIEW programming course has been offered at Aoyama Gakuin University in Tokyo. It is a multi-disciplinary engineering course intended to help provide better engineering education; enrolment consists of students from various science and engineering departments. The class is organized to provide both theoretical and hands-on experience in graphical programming. Every student uses his/her own laptop computer in the classroom, and hands-on lectures are conducted in each session. Students use LabVIEW Student Edition software as their graphical programming environment and a USB-type portable data acquisition device (NI myDAQ) as a hardware platform [19].

The LabVIEW programming course covers the following topics:

- Virtual instrumentation (VI).
- The LabVIEW programming environment.
- Execution, debugging, and handling errors.
- Data types and structures.

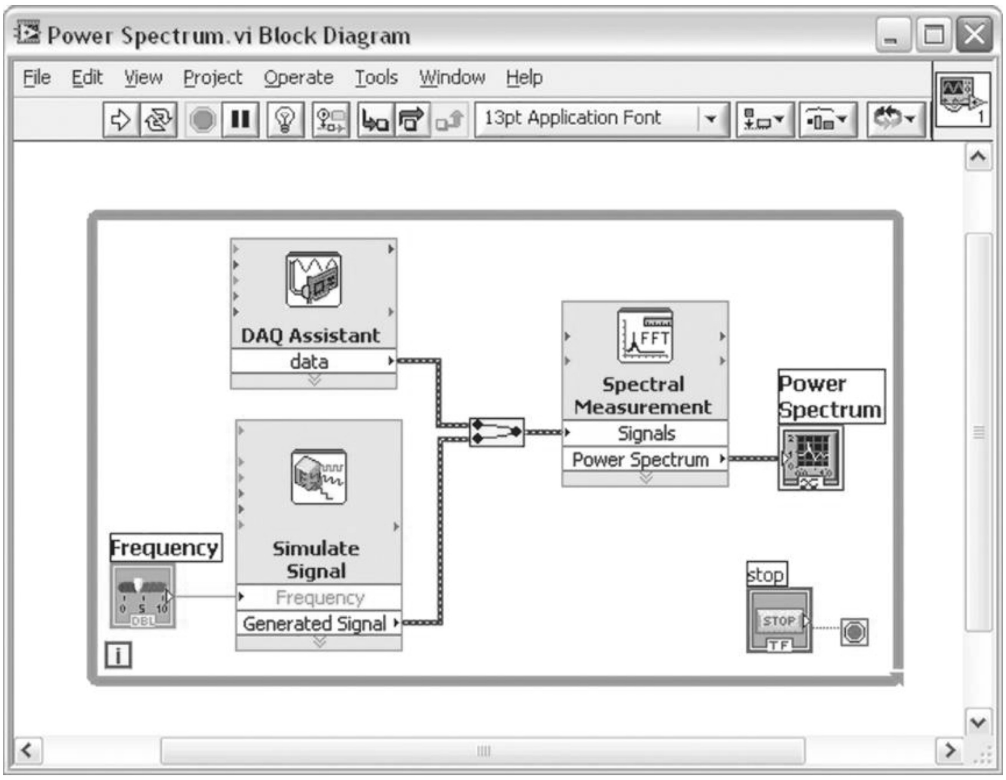

Fig. 1. LabVIEW graphical programming environment.

- Arrays and clusters.
- Subroutines and VI projects.
- Charts and graphs.
- Strings and file inputs/outputs.
- Data acquisition using portable hardware devices.
- Applications of graphical programming.

For the first few sessions, the class employs traditional in-class teaching approaches using slides, demos, and student assignments. Then, e-learning technology is introduced to facilitate students' understanding and the development of their programming skills. In other words, a single group of students receives only traditional programming instruction at first, and then has the option of pursuing advanced studies in a blended environment using an e-learning system. The traditional course runs for 15 weeks, with 30 hours of teaching time. However, e-learning time is determined using student total access to the system and varies according to student interest and motivation.

In their hands-on projects, students acquire analogue or digital signals from various sensors such as actuators, photodiodes or microphones using NI myDAQ and LabVIEW, in the PC environment. They apply additional algorithms to build PC-based automation systems, such as a speech-recognition-based on/off system, autonomous robot navigation, and image processing for their design projects.

Table 1 shows the number of students enrolled in LabVIEW programming course. These students came from various departments and had no experience in LabVIEW.

2.2 *E-learning system*

The traditional, face-to-face course was necessarily limited by the number of instruction hours available. In it, the content only covered fundamental techniques in LabVIEW programming. For this reason, e-learning content was introduced to address the gaps. The e-learning system provided videos and text-based tutorials for each topic, and students could easily navigate and search for them according to personal interest or need. The students were encouraged to use the e-learning portal in order to review specific topics and to develop their technical design skills. For this purpose, free access to the portal was provided to each student.

Table 1. Student enrolment

Departments	Course attendees
Information science	7
Electrical & electronics engineering	10
Mechanical engineering	13
Basic science	5
Bio-science	4
Total students	39

The LabVIEW e-learning system was developed by National Instruments Japan Corporation to facilitate the use of LabVIEW in the Japanese language. The system is based on Logosware Platon software and covers 157 topics requiring approximately 30 hours of e-learning time, all related to the teaching of graphical programming with LabVIEW to science and engineering students and engineers. The e-learning content includes various one-topic videos (each 5–15 minutes long), reading materials, and short quizzes. The e-learning portal is organized in six main sections:

- LabVIEW programming I.
- LabVIEW programming II.
- Data acquisition and analysis.
- FPGA (field programmable gate array) programming.
- Real-time programming.
- Image acquisition and processing.

LabVIEW programming I and II cover basic, intermediate, and advanced topics concerning the programming environment, while data acquisition, FPGA, real-time, and image processing introduce practical applications of LabVIEW that can be implemented in student design projects via various plug-in hardware devices. The e-learning system was available to all students until the final exam.

2.3 *Blending method*

The e-learning system was activated after the first several weeks of the traditional course, and was available to all students. However, actual usage of e-learning was driven mainly by several couching activities and by student motivation. Face-to-face instruction and the e-learning system were blended using the following techniques.

1. E-learning demo: Traditional, face-to-face teaching approaches still dominant in engineering education, especially in Japan. To ensure that all students had basic e-learning skills, we dedicated one class session to demonstrating the main features of our e-learning portal and the students to use the system proactively. In particular, we introduced the students to the video- and text-based on-demand e-learning modules provided by the system. These basic tools facilitate students' self-paced study and help them master graphical programming skills by demonstrating advanced techniques and providing real examples.
2. Course website: The Moodle course management system was utilised to disseminate digital teaching materials such as sample programs, PowerPoint slides, and weekly design project assignments. Periodic updates and reminders

were sent from the system to encourage students to access the portal. Student access of the portal increased after scheduled Moodle announcements reminding them that it was available.

3. Design projects: Project-based learning offers a wide range of benefits to both students and teachers in higher education [20, 21]. To complete projects successfully, students must participate in active roles: inquirer, problem-solver, decision-maker, and investigator. Working in groups of four or five, students initiated several design projects and presented them in the classroom. The projects were designed to require the students to investigate new programming techniques and re-visit certain topics covered in the classroom. Typical projects included a voice-recognition and voice-modifier program, a light detection system for an automatic door opener, an earthquake detection device for home safety, and a remote vehicle-control system.
4. Certification test: We adopted the official LabVIEW certification test as a way to assess and validate the programming skills of students; this was done as the final exam for the course. This certification test also provides an accreditation that is useful for employment not only in Japan but also worldwide (that is, it is accepted as a global standard). Students were therefore highly motivated achieve certification as they completed the short quizzes and reviewed the specific topics of the programming environment.

In addition to these blending methods, student assessment also played an important role in blending learning in our course. Students' grades were evaluated based on their design projects (D, 40%), their submitted reports (R, 40%), and the results of the final certification exam (C, 20%).

Students were encouraged to use the e-learning system for every step of the assessment process. However, usage was not the same for each student, but instead varied according to their different expectations, needs, and motivations for taking the course. This kind of variation should be investigated in future experimental studies and student surveys.

3. Experimental results

This section describes the data collection procedures used in this study, presents the results, and discusses their implications for the understanding of e-learning usage and its impact in blended learning. Data were generated by records of individual student use of the e-learning system, student survey reports, and certification exam results.

In this e-learning system, each student is given a unique user ID and password which enable him or her to access all e-learning functions. Since students use their IDs to log in to the system, it is easy to acquire their access history for research purposes. These students averaged 4.7 hours of e-learning usage, covering an average of almost 15% of all digital content, during the three-month period of access availability.

3.1 Actual usage of e-learning

Understanding the actual usage of an e-learning system used in blended learning is very important, because it enables us to effectively design and customize e-learning material according to student needs. Several contextual and individual factors must be taken into consideration, including students' capabilities, motivation, and prior knowledge and experience [22]. By encouraging students to use e-learning course materials and share their views on them, we can obtain valuable insight into how to improve e-learning course design, and thereby improve student engagement and certification test achievement. As many teachers in blended learning classrooms already understand, a positive attitude is crucial for the development of a truly interactive and dynamic learning community, which requires considerable time and energy.

In order to quantify e-learning usage, we measured the time students spent on each topic and compared the results with those of face-to-face learning. E-learning time was extracted from the system by student ID. In contrast, face-to-face learning time for each topic was calculated based on the number of lecture slides. Fig. 2 shows the actual learning time allotted to each topic, both face-to-face and via e-learning. On the horizontal axis, topics 1–90 cover fundamental content, 91–95 cover certification-test-related topics, and 96–157 address advanced topics. Overall learning times for face-to-face learning and e-learning, respectively, were 30 hours and 4.7 hours.

The results show that the e-learning portal was used extensively by students to help them pass the certification test—a result that can be seen as a big spike in the graph—and to review some fundamental topics. The distribution of the learning topics, for both face-to-face and e-learning, is given in Table 2. For simplicity, we have divided the covered topics into three categories—'Basic', 'Certification', and 'Advanced'—as outlined in the previous paragraph.

We should emphasize that face-to-face learning did not cover any certification-test-related topics because of limitations on in-class time. However, among the materials archived on the e-learning system were useful training materials for the exam, such as short videos, sample questions, and examples

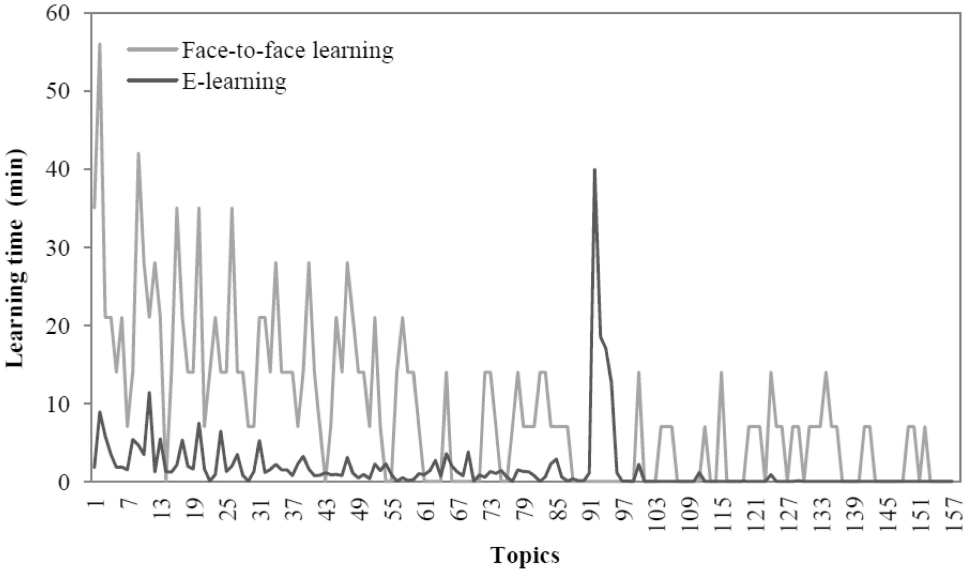

Fig. 2. Student learning time for each topic covered in face-to-face learning and in the e-learning system.

Table 2. Distribution of topics covered face-to-face and via the e-learning system

	Basic	Certification	Advanced
Face-to-face learning	84%	0%	16%
E-learning	64%	34%	2%

of common mistakes. Thus, it was not surprising to find that 34% of students' total e-learning usage was devoted to certification-test-related topics.

Next, in order to understand the students' motivation to use the e-learning system, we conducted a student survey. The questionnaire consisted of 15 items designed to address students' motivations toward three main categories of content: basic LabVIEW features, the LabVIEW certification test, and advanced LabVIEW features. Students responded to statements provided on the survey using a seven-point Likert-type scale ranging from '1 = Strongly Disagree' to '7 = Strongly Agree'. Overall scores were then calculated for each question and compared to usage pattern results, with a focus on students' desire to do well on the certification test. Students' self-reported motivation matched their usage patterns: motivation scores were highest for the certification-test-related items in the survey. The top three reasons students gave for using the e-learning system were also related to their desire to score well on the certification test, as Table 3 shows.

Students' main motivation to use the e-learning system was that they felt it would help them pass the certification test, acquire better employment opportunities, and gain confidence in their engineering

Table 3. Results of student survey on the use of the e-learning system

Ranking	Questions on why they used the e-learning system	Student motivation
1	I thought certification would be advantageous to get better employment.	Certification
2	I wanted to gain confidence by passing the qualification exam.	Certification
3	I wanted to be recognized as an engineer by getting the certification.	Certification
4	I wanted to know what else I could do with LabVIEW.	Advanced
5	I planned to deepen my experience so that I can use it in the future.	Advanced
6	I wanted to get a course credit by passing the exam.	Certification
7	I enjoyed graphical programming, so I used e-learning (to learn more).	Basic
8	I wanted to learn more about building systems with LabVIEW.	Advanced
9	I thought that I could get a promotion in the future if I got the certification.	Certification
10	I enjoyed e-learning because it was easy to practice and revise topics.	Basic
11	It was helpful using the e-learning portal.	Basic
12	I was only interested in the fundamental features of LabVIEW.	Basic
13	It was fun to see programs built in LabVIEW.	Basic
14	I wanted to build advanced systems using LabVIEW.	Advanced
15	I thought that I could use LabVIEW for my master's dissertation.	Advanced

ability. Practicing basic topics and learning advanced features of the system were lower priorities. These results show that the integration of the certification test into our curriculum was a driving factor in students' use of the e-learning system. Students were mostly motivated to pass the certification test because of the employment opportunities they felt it could facilitate or the confidence it might bestow; however, they were not motivated by the assessment process itself.

3.2 Impact of the certification test

Since e-learning was mainly used as a means to improve students' chances to pass the certification exam, in this section we investigate the impact of e-learning on exam scores. The certification test, comprising 40 items and lasting an hour, was developed by the National Instruments corporate office. It serves as a global standard for accreditation as a NI Certified LabVIEW Associate Developer (CLAD), the first level in a three-level NI LabVIEW certification process. Certification at this level indicates a broad working knowledge of the LabVIEW environment, a basic understanding of coding and documentation best practices, and the ability to read and interpret existing code. Certification implies the assessment and validation of an individual's LabVIEW development skills, showing that they are adequate for the individual to take on projects or advance professionally in this field.

In general, we would expect learning time and test results to be correlated. Fig. 3 shows the total learning time that the present group of students spent receiving face-to-face instruction and using the e-learning system, respectively.

Face-to-face learning, or lecture time, is proportional to students' attendance rate; therefore, it is virtually the same for each student, and it is difficult to identify differences in student experience by looking at this data. In contrast, e-learning time as extracted from the system reflects students' personal access patterns and is very different from student to student. The data indicate that students 30 to 39 used the e-learning system extensively as compared with the others.

The certification test results are shown in Fig. 4.

As seen in the figure, the lowest and highest certification test scores were 27 and 75 out of 100, respectively.

When we look at Figs 3 and 4 together, we can see that total student learning time is correlated with certification test results. However, face-to-face learning time is pretty much the same for all students, so it is very difficult to measure its real impact on certification test scores. In contrast, e-learning time and certification test results also seem to be correlated, since there was significant amount of access on certification-related topics, and here it is easier to determine the real effect due to differences in access time among students.

In statistics, 'correlation' refers to the degree of correspondence or relationship between two variables. To understand the relationship between e-learning access and certification test results, correlation coefficients are calculated as given below, where x and y represent e-learning access and certification test data, respectively:

$$Correlation = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (1)$$

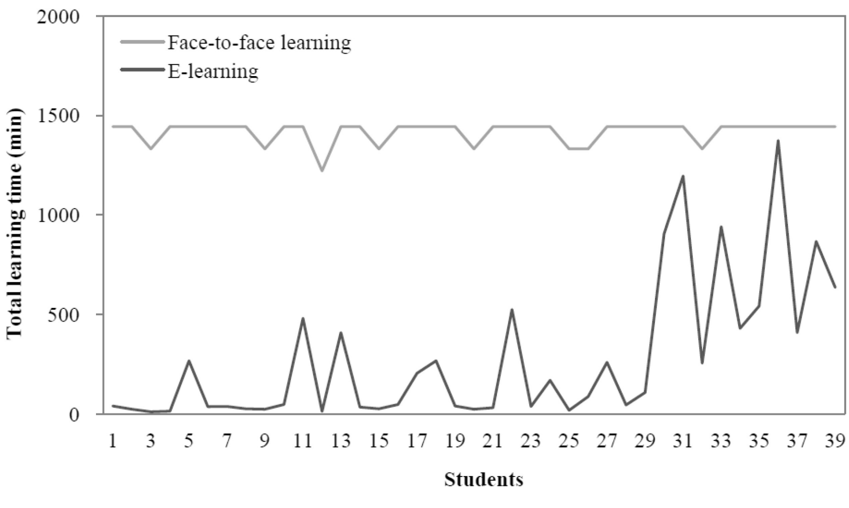

Fig. 3. Total learning time of students. Face-to-face learning time varies with student attendance rate in class. E-learning time is proportional to the student's total time accessing the e-learning portal.

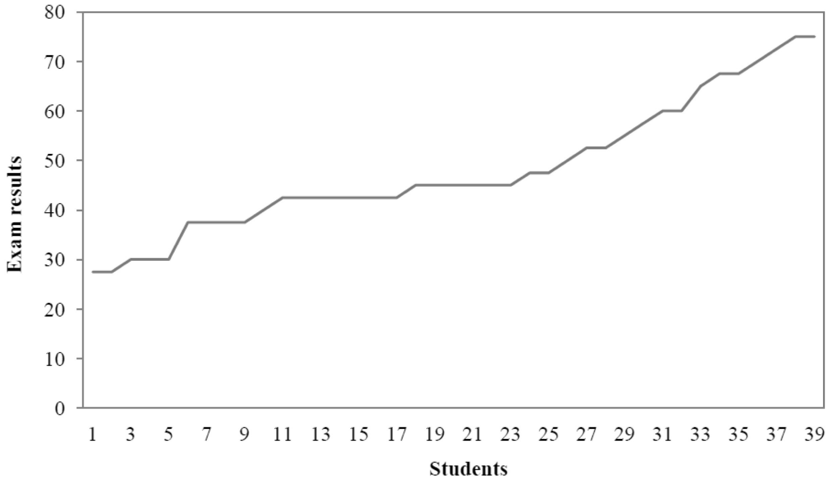

Fig. 4. Certification test results for students enrolled in the LabVIEW-based programming class

Table 4. Comparison of student learning times and test results

	Face-to-face learning (min)	E-learning (min)	Certification test results
Group 1: Almost no e-learning	1402	30	39.7
Group 2: Considerable e-learning	1432	516	56.1
All students	1417	279	48.1

Here, $\bar{x}$ and $\bar{y}$ are the average values and n represents total data points, for a value of 39 in our case. A correlation coefficient can range from -1 to 1; in our case, the correlation coefficient was 0.70 or 70%, indicating a strong positive correlation between e-learning time and certification test results. In contrast, the correlation coefficient between face-to-face learning time and certification test results was 0.15, which means that there was almost no correlation.

In order to understand the actual impact of e-learning on certification test performance, students were divided into two different groups by level of e-learning usage. For Group 1, e-learning access time totalled less than 45 minutes, and for Group 2, more than 45 minutes. Our experimental studies show that less than 45 minutes of e-learning access time was not enough to improve programming skills, nor was it adequate to pass the certification test. In general, students had to spend an initial 10 to 15 minutes getting familiar with the learning environment and finding the content they were looking for. In addition, the certification modules require more than 60 minutes to complete the videos and practice quizzes. Therefore, we assumed that students whose e-learning access time was less than 45 minutes had not completed the certification-test-related topics.

Based on this categorization, we assigned 19 students to Group 1 and 20 students to Group 2. Then, we calculated average learning times for face-to-face learning and e-learning as well as certification test results for each group. The results are summarized in Table 4.

Face-to-face learning time was almost the same between Groups 1 and 2, with 1402 and 1432 minutes, respectively. However, e-learning time was significantly higher in Group 2, with 516 minutes, as opposed to Group 1, with only 30 minutes. Finally, certification test average scores were 39.7 for Group 1 and 56.1 for Group 2, respectively. Thus, it can be seen that students who used the e-learning system achieved certification test results almost 40% higher than those who had face-to-face learning experiences only.

However, there may be other factors that account for these results—for instance, perhaps students who enjoy using the e-learning system are also more inclined to take advantage of its opportunities, and also, independently, they may be the ones likely to do better on the certification test. In addition, we should note that these results are only valid for our particular case study, and may not be the same for other programming courses (or courses in other areas), because the impact of blended learning can vary by content, digital delivery method, e-learning incorporation technique, and student motivation.

4. Conclusions

In this case study, an efficient blended learning approach was introduced in order to examine the impact of the e-learning system by which it was implemented. The implementation showed that our blended approach is suited to teaching graphical programming at the post-secondary level. A traditional course was blended with e-learning technology that provided various means of increasing the programming skills of students. Individual data analysis and student survey results showed that e-learning was mainly used to help students pass the certification test exam in order to secure better employment opportunities. The impact of e-learning was significant for students who spent a notable amount of time looking at key content via the system, as compared with those who did not use the e-learning portal; this effect was seen especially in the certification test results.

However, the impact of blended learning is dependent on integration method, student needs, and student motivation. This case study has revealed important information in terms of understanding student motivation in particular, which should help in the design of efficient blending learning environments for better engineering education. Based on these results, blending methods can be re-considered to increase overall use of e-learning, which we can expect will help students achieve greater success in engineering courses and improve their engineering skills.

Finally, we should note that our findings represent only a particular group of students in a specific programming course in an engineering faculty in Japan. The general impact of blended learning might differ for other engineering courses and students, courses and students in other fields, and different cultural contexts. Further investigation is needed to produce broad and deep insight into these differences. It seems clear, however, that in the future, the adaptation of blended learning to various courses and student populations can be considered as a possible way to provide better engineering education and enable students to meet various engineering and educational challenges.

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