Rotational Blended Learning in Computer System Engineering Courses

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***Abstract*— Contribution: An original application of individual rotation to blended learning, which mixes e-learning, discussion groups (seminars), practical laboratory work and self-motivated tasks called 'mini-projects'.**

Background: In examining the changing practices towards students' transferable skills in higher education, current teaching needs to devote much more attention to using multi-modular teaching methods to foster students' key transferable skills, such as logical, analytical and creative thinking.

Intended outcomes: Rotational blended learning is intended to maximize students' engagement and improve educational outcomes during the learning process.

Application design: A rotated form of existing teaching methods—e-learning, seminars, and group projects—was proposed. A quasi-experimental design, involving classroom observation, student surveys and overall results, was used with two cohorts of computer system engineering students, one a controlled cohort taught using traditional techniques and the other an experimental cohort taught using a novel rotational blended system.

Findings: The influence of blended learning on the subsequent development of critical transferable skills was demonstrated. Results suggest that rotational blended learning is an ideal way to address these challenges, since it allows computer engineering students to reassess and enhance the core skills and competencies they need to acquire in their learning experiences.

***Index Terms*—Blended learning, computer engineering, group projects, mixed methods research, mutual learning model**

I. Introduction

Computer engineering graduates require a wide range of skills and advanced analytic abilities, including a sound understanding of electronic engineering and a high level of proficiency in computer programming [1]. A major problem that educators face in teaching these skills is that the vast majority of students only focus on the completion of their projects or on remembering facts that will appear on exam papers. Their learning experiences are preoccupied by completing technical skills-related assessment, instead of evaluating their individual educational outcomes, transferable skills and subject areas they may need to improve on. Empirical evidence demonstrates the efficacy of the rotational blended learning framework, which creates an entry point to transition traditional ways of teaching towards blended learning.

Graham et al classified satisfactory blended leaning into three styles [2]:

1. Combining instructional modalities;
2. Combining instructional methods; and
3. Combining on-line and face-to-face learning.

Generally speaking, the first two styles are almost totally media-centred and ignore the tutor's function in the learning process [3]. For instance, the simple combination of internet-based e-learning and face-to-face teaching has become a popular form of blended learning [4], even though it is often quite inflexible and has to be readjusted for each new course. Although the development of internet-based online teaching technologies may accelerate the education process, such improvements are in general only achieved with careful pedagogic design. Simply mixing existing face-to-face and e-learning methods does not inevitably lead to noticeable enhancement of learners' understanding, because the various models in Graham's style need be carefully applied to those learning tasks [5].

Unfortunately, an equilibrium between e-learning and face-to-face environments is not easily achieved [6], [7]. Recently considerable attention has been given to improving the quality of education through blended learning methods [8], [9], to develop skills by engaging and challenging students [10]. Fostering research and analytical skills in undergraduates, however, demands a more systematic approach.

This paper reports an original rotational blended learning style, using multiple stations, as a proposed solution to this problem; it enables students to learn transferable skills and then apply them at stations optimised for the specific skill. Although previous studies have studied blended learning and e-learning in higher education, very few have provided a rotational learning style with widely available e-learning materials.

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II. METHOD

The rotational blended learning style was integrated with internet-based e-learning technologies and a range of specific teaching methods. The new pedagogic arrangements were applied in a live teaching environment, to the entire annual cohort of a final-year module, 'Systems Engineering Technologies', which was part of a Computer Science honours degree program. Systems Engineering Technologies is a mixed

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computer hardware and software module, concerned with developing skills in implementation of embedded and real-time systems; it runs for twelve weeks, with a one-hour lecture and three hours of tutor-supported time available each week. The supervised parts of the blended learning method discussed here took place during the last two of the tutor-supported hours, with different kinds of events being available concurrently to different groups of students. In addition, the students were expected to devote at least six hours per week to self-study. The previous year's cohort, which used traditional pedagogic methods, was used as a control group. This approach was necessitated by the institution's regulations not allowing variation of assessment methods within a cohort.

Student grades from the control group and the experimental group demonstrated the efficacy of rotational blended learning into the classroom. Various learning methods can also be combined effectively, without recreating the whole process, to develop crucial transferable skills. Students in the control group who started with the e-learning rotation often tended to voluntarily go to the seminar rotation to review their learning to gain further understanding. However, the students who started with mini-project were much more engaged during the seminar rotation than the students who started with e-learning. It is noted that students' engagement during the first rotation may be affected by their previous knowledge, especially if students have already covered their given topic.

As previously discussed, since the host institution's regulations require the same assessments for all students in a cohort, the study was run sequentially over two years. The 2015 cohort of 55 students, taught using the traditional combination of lectures and workshops, was used as a control group. The 2016-17 cohort of 66 students was taught using the new rotational blended learning method. Both groups were taught by the same members of staff, had the same resources available and no exceptional circumstances occurred in either year, so there is no indication that they should be less comparable than two groups taken from the same cohort. The overall results of each year were very similar, although assessment moderation processes tend to ensure this outcome in any case. On average there were two female students per year; no differences were detected between male and female students in the final evaluation. In both groups, students were also asked to take formative assessments (portfolio work).

A. *Course Content and Learning Outcomes*

The Systems Engineering Technologies module was the final-year contribution to a curriculum strand on the fundamentals of computing and systems engineering, which started in the first year with an introductory module 'Fundamentals of Computing' and continued in the second year with a module 'Operating Systems and Computer Architecture'. The module discussed here enabled students to build on this prior knowledge and skill set to integrate applications of existing embedded systems and technologies into computer system engineering paradigms, and to learn how to investigate advanced, state of the art concepts and technologies, including how this knowledge can be harnessed to improve control and data flow across existing stand-alone systems. The aim was for students to develop the ability to build upon theoretical principles with practical, cross-platform applications.

The syllabus for the module was oriented towards building computer engineering concepts using two embedded platforms, the Freescale/NXP KL25Z board and the STmicrocontroller MSCBSTR9. Both of these boards are popular targets for embedded system courses, providing flexible systems platforms which have available development resources well suited to educational use. The module also taught final-year computer engineering students to acquire new competences related to C programming in microcontrollers, general-purpose input/output (GPIO), bus systems, interrupts, memory and pointers, and real-time operating systems.

Three main module learning outcomes are that students must:

1. Demonstrate a broad understanding and knowledge of the principles of systems engineering technologies.
2. Apply appropriate theory, technology and techniques to the design of computer systems.
3. Demonstrate and apply their understanding of the essential facts, concepts, principles, theories and practices enabling graduate employment in computer systems engineering.

B. *Rotational Blended Learning*

The rotational blended learning framework used three elements—e-learning, mini-projects and seminars—to teach the material covered in the module. That material was divided four sessions which operated sequentially, with each block being available for two weeks. The number of blocks was determined by considering the number of students enrolled, the tutorial support available, and equipment resources. The specific format adopted was formulated to allow tutors to change the number of rotations and iterations within the block as needed: $N_{iterations} = (N - G) * N$, where N is the number of sessions and G is the number of groups. Each block is taught through the three learning elements, known as "learning stations":

1. Internet-based e-learning: six topics that were to be addressed using internet-based e-learning materials were listed in the module syllabus , with recommended links for free course materials to allow students to study at their own pace. Relevant video demonstrations on the single-board computer used to support the practical work, from Freescale NXP, were provided for students as learning material; these resources were not only used in class, but were also used for self-study with RSS feed links to topic-related seminar discussions and new technology updates. Quizzes were given to test students' knowledge after completion of the e-learning station. As was common to modules within the Computer Science program, this module used portfolio-based assessment, and the results from these and the quizzes were available as evidence of achievement of the module's learning outcomes and could contribute up to 20% of a student's final grade.

2. Mini-project exercises: students were paired and given mini-projects tasks that allowed them to demonstrate their acquired knowledge of an assigned topic. The exercises were to be undertaken within a laboratory session, commonly called a

'workshop'. The topics to be addressed within a particular workshop were rotated according to student groups, as shown in Fig. 1. Upon completion of each workshop students were asked to demonstrate their results in 'show and tell' periods.

3. Seminar discussion: Seminars were organized around the four session blocks, ensuring that one or two topics were available for each of the twelve weeks of the module, as illustrated in Fig. 1. Students could choose which topics to attend, so long as the attended seminars around at least four topics over the whole module. In addition to the seminar material, a discussion was included in the first 15 minutes of each seminar class to help students understand how to move onto the next block in their rotation and for teachers to see if students needed support for the current block.

During the seminar tutors posed practical questions for discussion and subject-related problem solving. After each seminar students were asked to submit a self-assessment. The mini-project had students complete a demonstration and then write an individual report. Tutors became guides in the classroom, allowing them a better sense of what students learned from their e-learning and efforts outside of class. This course structure encouraged students to be responsible for research and information gathering by having them do the assigned mini-projects. They were also able to carry out internet-based e-learning inside and outside of class contact time.

	1	2	3	4	5	6	7	8	9	10	11	12
Group1	E1	P1	S1	S2	E2	P2	E3	S3	P3	P4	S4	E4
Group2	S2	P2	E2	E3	S3	P3	E4	P4	S4	E1	S1	P1
Group3	E3	S3	P3	P4	E4	S4	S1	E1	P1	E2	P2	S2
Group4	P4	E4	S4	E3	S3	P3	E2	S2	P2	S1	E1	P1

Session number	Session 1		Session 2		Session 3	Session 4
Topics name	C Programming in Microcontroller	Memory and Pointers	GPIO	Bus Systems	Interrupts and Timers	Real-time Operating System

E: stands for E-learning; S: stands for seminar; P: stands for project

Fig. 1. Organization of rotational blended learning. Week 1 to week 12 are orgnised with e-learning, seminar and projects. E1 refers to the E-learning for session1; P1 refers to the mini-projects for session 1; S1 refers to the seminar with topics from session1.

Each student needed to complete four mini-project programming tasks (two based on Freescale KL25Z and two based on STMicontroller MCBSTR9). Students were assessed on mini-project exercises by giving a live demo, and by completing answer sheets to demonstrate achievement of their learning outcomes. Throughout the course, as a formative task, students were asked to design deliverables at each rotation station and then write a short written report on each mini-project. At each milestone of their final project, individuals had to provide reports and give demonstrations to show the functionality of their system. Sample mini-projects included:

1) Capacitive touch sensors: Students designed a program that used the Freescale KL25Z capacitive touch functionality as a switch to control an LED, to implement the following tasks: a) If the student touches the right of sensor board, the blue LED should go on. b) If the student touches the middle of sensor board, the green LED should go on.

2) Mass storage and display: Students designed a program that read a text file from a USB mass storage device which was then displayed on a LCD screen with scrolling words. Speed could be changed via the potentiometer available on the MCBSTR9 board.

Four other mini-projects were available, including use of accelerometers and USB input/output, exploration of a real-time operating system, and development of a simple robot.

C. *Experimental Procedures*

The evaluation of each student's performance was based on continual formative assessment of each rotation stage using quizzes and tests that enabled students to reflect on their own progress. The portfolio-style assessment used in this module aims to avoid purely summative assessment. Rather, all assessments are formative in nature and some are summated to produce the final grade.

Critical thinking and analytical skills were assessed by peer evaluation during the pair programming tasks, while technical skills were assessed by quizzes at end of the e-learning sessions. The final grade was calculated from a summation of some of the aforementioned work: 20% from summation of four mini-project tasks (assessing students analytical skills); 60% from two individual projects (assessing students research skills and technique skills); 20% from the quizzes at end of each seminar through a virtual learning environment including one-best-answer and true/false questions (assessing technical skills).

Each assessment item was marked at the end of each rotation. For the e-learning and mini-project rotations, both pre-session tests and pro-session tests were designed to indicate students' baseline ability and individual background limitations. These self-assessments did not contribute to students' final grade. Each mini-project excise was given a deadline, to allow groups to organize and complete their task within class hours. The objective of the mini-projects was to stimulate participation and encourage students to take responsibility for their own studies; a group's successful was reflected by their final grade. After each seminar, students were also asked to attend multiple choice in-class tests, which covered the topics that students had chosen to study.

At the end of each mini-project session, students were required to submit their peer-assessment feedback; the person who received the highest peer evaluation receives a bonus in the final course assessment.

III. Results

The study was evaluated by the pass rate and the student course experience survey. The use of blended learning improved the pass rate, and greatly improved the achieved grades, compared to the previous year's control group that used traditional learning method with lectures and projects.

A. Data Analysis

All students successfully completed the quizzes and mini-workshops, meeting the required learning outcomes. In the control group, students achieved an average of 68%, while students who were taught using the blended learning techniques a similar percentage of 69% with no noticeable improvement.

However, the average pass rate (> 40%) in the blended learning group was 100%, much higher than the 75% the control group achieved. A quasi-experimental design was used to estimate the impact of an intervention on the experimental group that used rotational blended learning method [11]. Samples were not randomly selected (in a quasi-experimental design) compared with the conventional sampling selection method. A specially designed independent variable in the quasi-experimental designs allows evaluation of the rotational blended learning strategies. To address the questions raised by the use of sequential groups, as described in Section II, pre-test/pro-test design and nonequivalent groups design were used as two classical quasi-experimental methods in this experiment. To find out whether there was a difference between the knowledge levels of two cohorts during the application, the pre-test results of two cohorts were analyzed via the independent T-test [12], Table I.

Table I: Comparison of pre-test results of the students in the 2015/16 cohorts and the 2016/17 cohorts

Cohort	2015/16	2016/17
Number of student	55	66
df	26	
P Value	0.9814	
T-test Value	2.1974	

There are no history results from this module to compare since this relatively new module only started in 2015-16. As shown in Table I, a two-tail analysis was tested to the null hypothesis: the experimental and control groups have similar levels of knowledge before the rotational blended learning was started. The value of T-test is 0.9814 with P> .05. This fails to reject a null hypothesis. To find out whether there was a significant difference between two cohorts, the post-test scores of the experimental and control cohorts were analyzed via the independent groups T-test.

Table II Comparison of past-test results of the students in the 2015/16 cohorts and the 2016/17 cohorts

Cohort	2015/16	2016/17
No. of student	55	66
Mean	11.44	13.45
df	26	
P value	0.003	
T-test Value	-4.97	

As shown in Table II, the mean difference of pre-test and pro-test in the control and experimental cohort were analyzed in the independent groups T-test. When Table II is examined, it seems that there was a significant difference in improvement between the control and experimental cohort. The null hypnosis clearly states that the improvement of the control cohort is less than that of the experimental cohort. The T-test value is 7.986 with P < .05; depending on this result, the null hypnosis could be accepted and it suggests that the learning improvement of the students in the experimental cohort was more effective on students achievement than the control cohort.

Table IV Assessment results in each rotation

Content	Quizzes	Mini-Projects Mark1	Mini-Project mark2	Peer review
C programming in microcontroller	82%	67%	76%	98%
Memory and Pointer	86%	76%	67%	76%
GPIO	90%	95%	98%	77%
Interrupt and Times	75%	85%	86%	87%
Real-time OS	60%	70%	77%	67%
Bus System	70%	76%	80%	68%

Table III shows the detailed results of the assessment of each rotation stage. Each student's mini-project report was marked by two members of staff to ensure equitable academic judgement. It is interesting that the results of quizzes and mini-project in each rotation station is not very consistent. This phenomenon is anecdotally quite common within the computer science subject area, where some topics are notoriously harder for students to assimilate than others, as discussed, for instance, by Mow [13]

Table III Assessment results in each rotation

Content	Quizzes	mark 1	mark 2	Peer review
Programming in microcontroller	82%	67%	76%	98%
Memory and pointer	86%	76%	67%	76%
GPIO	90%	95%	98%	77%
Interrupt and Times	75%	85%	86%	87%
Real-time OS	60%	70%	77%	67%

Bus Systems	70%	76%	80%	68%

B. *Student Sample Work on Analytical Skills*

Students' analytical skills can be demonstrated through their understanding of computer system engineering topics and the quality of their programming in electronic systems. The interrupt, selected as one of the most confusing of key computer engineering concepts, was used as an example to demonstrate how an improvement in students' analytical skills can also enhance their technical skills.

Figs. 2 and 3 show the assignment on the interrupt topic. Students were asked to create a program that displayed text and symbols every second on a Hitachi HD44780 LCD screen. Due to a misunderstanding of the interrupt, the first group of students, taught entirely by lectures, failed to demonstrate the use of handling interrupt routine, although their demonstration did show a working function, Fig. 2. The experimental blended learning group students managed to use an interrupt routine to complete the project successfully, Fig. 3. This suggests that students taught entirely by lectures appear to predominately focus on the completion of functions, often resulting in inaccurate or incorrect results. Rotational blended leaning provides a better combination of e-learning and face-to-face support, which allows students to reflect on their understanding of key ideas and implement this for practical use.

```
#include <91x_lib.h>
#include <stdio.h>
#include "sio.h"
#include "LCD.h"
/*TIM0 interrupt routine define in IRQ.c */
extern __irq void TIM0_IRQ_Handler(void);
/*TIM0 interrupt flag */
extern char flag1;

void wait (void) { /* wait function */
}
void main (void) {
/*LCD setup ........................................................*/
/* UART0 Setup...................................................*/
/* Configure and enable IRQ for Timer (TIM0)*/
while (1) {
        /* each time move '>' symbol
        if ( flag1 != 1 ) continue;
        Lcd_print("->");
        flag1 = 0;
        }
}
}
```

Fig. 2 Interrupt assignment student sample in the control group

```
#include <91x_lib.h>
#include <stdio.h>
#include "sio.h"
#include "LCD.h"
/*TIM0 interrupt routine define in IRQ.c */
extern __irq void TIM0_IRQ_Handler(void);
/*TIM0 interrupt flag */
extern char flag2;
extern unsigned int g_ts1;

void wait (void) { /* wait function */
}
void main (void) {
/*LCD setup ........................................................*/
/* UART0 Setup...................................................*/
/* Configure and enable IRQ for Timer (TIM0)*/
while (1) {
        for(k=0;k<17;k++){
        set_cursor (k, 0);
        lcd_print ("->");
        wait();
        lcd_clear();
      }

}
```

Fig 3. Interrupt assignment student sample in the experimental group

C. *Student Satisfaction*

Evaluation of students' transferable skills in research and analytical analysis was based on continual assessments during the semester and on their two short professional reports. Additionally, a peer assessment questionnaire of students' critical analytical skills was designed, with an integer score ranging from +5 (strong agreement) to -5 (total disagreement), Table IV. The two cohort scores (control and experimental) were averaged to give mean figures and linearly converted to percentages. The low score reflects the fact that most students undertaking the System Engineering Technologies course graduated from other computing network courses; these students had not fully developed hardware analytical skills crucial to this course. In total, 95% of students who completed the survey gave mostly positive feedback to the rotational blended learning environment, giving three main reasons for this:

1. A blended learning environment allows students more opportunities to carry out revision.
2. Students were able to learn at their own pace, which allowed them to grasp fundamentals proficiently, and practice them.
3. Blended learning also improves the level of in-depth thinking developed from specific examples and scenarios that can be applied to wider problems and tasks.

On analyzing e-learning practice and usage, it is exciting to see students harness the power of freely available information to successfully solve problems on new tasks as another major finding in this study. However, this learning process also involves a lot of errors, as students can often misunderstand new, essential information without teaching guidance. Students should also understand how much trust to place in any given piece of information; in a descriptive study of the use of internet based on online e-learning, students raised their awareness of the accuracy, completeness and consistency, particularly in unsourced information [14].

IV. CONCLUSION & DISCUSSION

A rotational blended learning pedagogic framework was designed and conducted with integrated internet-based e-learning, mini-projects and topic centered seminars into a three-in-one rotation model to maximize students' engagement and improve educational outcomes during the learning process. The quasi-experiments conducted in the 2015/16 and 2016/17 cohorts demonstrated the systematic rotation.

Equipping students with transferable research, analytical and technical skills is critical to improve education outcomes. These skills foster students' ability to search for, synthesize and disseminate complicated information, allowing them to pool knowledge and compare notes with other resources to develop a full understanding of the subject. After evaluating the reliability and credibility of different information sources with the integration of existing systems and technologies, students can finally applying them in various computer system engineering-related jobs.

Rapid changes in new technology require researchers to equip students with a new skill set that goes beyond the traditional classroom; this combination of complex skills may be best taught through a blended learning environment. Taking advantage of existing teaching modalities, rotational blended leaning using three various learning models (e-learning, seminars and group projects) can greatly improve the traditional one way style teaching method. As single blended learning styles reduces the chance for students to discover and construct essential information for themselves, rotational blended learning methods are a great improvement, allowing students to draw from their unique prior experience and learning styles to construct new knowledge and achieve learning outcomes.

Rotational blended learning requires more preparation time, but this is compensated for by the invaluable transferable skills students acquire. Although students are given more assessment at each station, and are required to be engaged, they are still highly motivated. However, which station of the rotational layout benefits students most requires further study.

Moreover, future work is needed to apply this rotational model as an improved mutual learning model in overall computer engineering program design. By gradually introducing this rotational leaning model, students will gain transferable skills from practical course work, propelling them to more exciting challenges and, inevitably, a more prosperous future.

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