AN INTEGRATED APPROACH TO TEACHING FIRST YEAR DIPLOMA IN BIOELECTRONICS

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Abstract
The traditional and widely used lecture/tutorial/practical (L/T/P) format of teaching was seen to be not as effective as desired. Student learning was artificially divided into 3 separate sessions – one where new material was taught, another where problems were discussed, and yet another where practical skills were learnt. Often these sessions were taught by different faculty members, resulting in a lack of continuity and fragmented learning.

It was also recognized that students learnt deeper when practical examples could be introduced early to reinforce theory taught. These could come in the form of real world applications, a design exercise or project work. This was of particular importance in the first year where content taught was more theoretical in nature as opposed to the more application based modules in the later years.

In addition, it was important that staff could highlight disciplinary linkages between the different modules so that students could be given a holistic picture of Electrical Engineering as soon as possible. This was difficult as different staff taught the different modules.

When the Diploma in Bioelectronics started in 2005, a pilot-run to make use of an Integrated Approach to teach a sizable portion of the first year curriculum was proposed. The L/T/P sessions were integrated into one. 3 technical modules totaling 405 hours were "combined" and assigned to one staff to teach. Lesson time was extended to 4 hour blocks so that staff could have more time to experiment in the way they taught.

At the end of the academic year, students from the pilot-run sat for the same sessional examination papers as those from other courses who were taught in the more traditional approach. The results obtained showed that students in the pilot-run did better than expected

Keywords: Integrated Teaching, Project based Learning, Lesson Structure

Introduction
First year students joining the School of EEE are required to take a suite of common modules. These include technical modules like Principles of Electrical and Electronic Engineering (PEEE), a 195 hour module; Digital Electronics (DE), a 120 hour module and Project 1, a 90 hour

module. For each of these modules, the instruction method used comprised lectures (L), tutorials (T) and practical laboratory sessions (P). They were taught over 2 semesters of 15 weeks each. Lectures took place in groups of 40, while students are formed into groups of 20 for tutorials and practicals.

The staff teaching each module was different. Within a module, the staff teaching the 3 components for each student also need not be the same. L/T/P sessions were spread across the week and were not timetabled in any particular order. In short, the teaching structure was quite fragmented in nature.

Meanwhile, academic staff were lamenting that students did not seem to be learning deeply enough. While a large majority of students did not have problems passing module examinations, they were often unable to recall simple concepts soon after being tested. They also had difficulty linking related material taught in different modules together and seemed unable to transfer their learning to solve real-life problems that were different from those found in textbooks.

The ability to train students to effectively transfer knowledge requires more than just the dispensing of technical content. It also requires students to be properly motivated, given the appropriate feedback, being able to learn actively, and apply metacognition to their learning [1]. The challenge of facilitating this was hindered by the fragmented nature of the existing lesson structure.

Some staff had tried to address this by introducing problem-based learning (PBL) into their modules. Students were given open ended or realistic mini-projects to solve. They worked in teams to come up with possible solutions, which were then discussed and presented to the class.

While PBL has been described as "the best way to learn" [2] and had the potential to be more effective and interesting, they required longer stretches of lesson time. They also required the same lecturer to be present to follow through with the teaching. The L/T/P lesson structure hindered this approach. Weekly tutorial sessions were typically only 1 hour long, while practical sessions were 2 hours in duration, once every fortnight. These were too short for effective interactive problem-based lessons to take place.

It became apparent that it was difficult to solve student's learning problems without changing the way lessons were structured. It was clear that for more engaging lessons to take place, a different lesson structure had to be implemented. It was with this in mind that the Integrated Program was piloted.

Implementation

The motivation behind creating the Integrated Program was to create a lesson structure and an environment within which deeper learning can take place. This was done to address the perceived weaknesses of an existing system as described above. It was piloted in the 4 classes of the Diploma in Bioelectronics (DBE) course in AY0506.

Another motivation behind the design of the Integrated Program was to have a teaching structure that enabled a teaching staff to experiment with new teaching ideas and methodologies, if he was

so inclined. It was also designed to be one where students had the potential to experience good interactive, blended and authentic learning.

Many features were built into the Integrated Program. These can be classified broadly under Lesson Structure, Teaching and Learning, and Assessment and Evaluation.

Lesson Structure

Grouping of Modules
3 modules, PEEE, DE and Project 1, were grouped together.

PEEE and DE are modules where key fundamental knowledge required by all EEE students are taught. They are standard modules found in many tertiary level institutions offering EEE courses.

Although interconnected, students are traditionally taught these 2 modules separately. As a result, they are often unable to see how one subject area relates to the other. Grouping these 2 modules together allowed the lecturer to highlight how topics are related whenever the opportunity arose.

In addition, although concepts taught in both PEEE and DE can be applied to many electrical and electronic devices they can be (and were) taught in a highly theoretical manner. It had been advocated that more hands-on be included in the teaching of engineering, not only to make it more interesting, but also because of its ability to teach details and issues that theory alone cannot impart [3]. Putting the Project 1 module into the group allowed us to create simple projects or design exercises that made use of theories taught and hence address this concern. This arrangement also enabled students to make use of their newly acquired knowledge in practical ways soon after learning them, thereby reinforcing it.

Project 1 as an Anchor
Project 1 module was also used to anchor theoretical concepts taught in PEEE and DE into a substantial project.

2 to 3 weeks were set aside at the end of each semester for students to do a substantial project. These projects were designed to anchor the learning from the semester together, and to demonstrate to students that all the theory that they had covered can lead to a useful project. There were 2 anchor projects in all.

Students would have already been tasked to work on parts of this project during the PEEE and DE sessions. These tasks may have been to design and breadboard certain related circuits, or to fabricate part of the project.

Project 1 time was set aside to allow students to work in teams to integrate all the circuits together, and form a much bigger project. It was hoped that the bigger project would be able to excite and motivate students better.

Reduction of Contact Time and Introduction of Independent Learning Time

Total contact time for the 3 modules was reduced from the original 13.5 hours per week to 12 hours per week. This was done primarily to relief the overall teaching load of teaching staff who now taught in groups of 20 instead of 40. It was also done to reduce the loading on the laboratory since teaching was now conducted there exclusively. These 2 features will be discussed in greater detail later.

To make up for the reduction of 1.5 hours in contact time, formal Independent Learning time was introduced. This allowed staff to share the responsibility of learning with the students who now knew that they were required to cover significant parts of the modules on their own. Independent Learning activities were self directed and often took the form of a project, a self-study section, a design problem, a challenging question or preparation work for a presentation. Invariably, students were made to work in small groups. The lecturer would then ensure that learning had taken place through planned activities, like group quizzes, class presentations, oral interviews etc., when students returned to the classrooms.

Research has shown that when done correctly, independent learners develop the values, attitudes, knowledge and skills needed to make responsible decisions and take action dealing with their own learning [4]. These were desirable traits that the school was looking for in its graduates.

L/T/P hours combined, 4-hour sessions

The L/T/P components were combined, and teaching was done in 4-hour sessions, 3 times a week. Combining the L/T/P hours in this way removed the artificial demarcation of learning activities that students were subjected to. It also solved the problem that some had of labs and tutorials being scheduled ahead of lectures. Teaching staff can now teach in a manner they deem most appropriate for the material to be covered. They may even interweave instructional and hands-on sessions if they wish, since instruction took place in the laboratory.

The 4-hour sessions also provided a good stretch of instructional time for staff to design and experiment with innovative or novel teaching methods. It discouraged staff from merely conducting a lecture and "forces" them to introduce more variety in teaching. At the very least, they will have to conduct some practical session together with their lecture (this was the default mode of instruction employed when new teaching material could not be designed and deployed in time). This feature in the IP was useful because there is ample evidence to show that students learnt better when the teaching activity is varied, and when learning is active.

The 4-hour sessions were also useful in implementing PBL type of instruction, which necessarily took more time to do.

Teaching and Learning

Same staff teaching all 3 modules

The same teaching staff was assigned to teach all 3 modules. This arrangement allowed him to teach the modules in a more holistic manner. The staff is able to link related concepts between the modules together, and use examples and mini-projects that cut through the different modules. This potentially gave rise to learning that is more integrated in nature.

Another obvious advantage of this arrangement, given the sheer amount of total contact time available, was that it fostered a closer relationship between staff and students. Staff would be better able to monitor and coach the weaker students, and challenge those who were able to do more. They would be able to know the strengths and weaknesses of each student intimately and develop them accordingly.

A Master-Disciple teaching model that emulated the traditional prolonged relationship between a master and his disciples had been piloted in the school before. In that pilot, selected students had a small group of staff assigned to teach them throughout the duration of their course within the conventional L/T/P arrangement. Feedback from students showed that they preferred to be taught by familiar faces with whom they had already built rapport with [5]. This study had led to its salient features being weaved into the IP lesson structure.

Teaching in Groups of 20

Traditionally, PEEE and DE lectures were taught in groups of 40 while the tutorial and practical components were delivered to groups of 20. Project 1 was taught in classes of 20 students.

The IP restructured this and lessons were delivered to classes of 20 throughout.

This gave rise to a slight increase in overall staff contact hours, which we then mitigated by cutting down on the face-to-face contact time in favour of formal independent learning.

Teaching done in Labs

All teaching was scheduled in labs where basic equipment like Power Supplies, Multi-meters and Oscilloscopes and basic electrical components like resistors, capacitors and ICs were available at all times. This arrangement was made to enable maximum flexibility in terms of teaching methodology employed. Often teaching may be better done by making students do something and discover concepts for themselves rather than telling them about it. Teaching in a lab allowed this to take place.

PEEE / DE taught in alternate 3 to 4 week blocks

When IP was piloted, a decision was made to explore whether it was better for students to concentrate on just 1 module intensely over a period of time, or to do 2 or more modules concurrently at a less intense pace. The teaching schedule was redesigned so that students would cover the PEEE module over about 10 to 12 consecutive 4-hour sessions (spanning a 3-4 week stretch), and then switch over to cover DE for about the same amount of time. At the end of each semester, students would also have a continuous 2-1/2 week stretch in which to do Project 1.

Assessment and Evaluation

Formative Quizzes

Formative quizzes were conducted in the middle of each 3 or 4 week block. These quizzes were designed to serve as feedback to both staff and students as to how much learning had taken place. The quizzes were MCQ type questions. No formal assessment weightage was given to them.

After each quiz, staff were required to go through the solutions with the students. Where necessary, certain concepts that had not been taught well could be revisited.

Continual Assessment
Soon after each 3 or 4 week block, a formal test was conducted. The test covered both practical and theoretical aspects of the material taught in the block. Although formative in nature, they had marks allocated to them. Weightage was set at 15% per Continual Assessment. A total of 3 continual assessments were conducted for both PEEE and DE over the academic year.

Common Sessional Examinations
To evaluate how students responded to the IP approach, all first year students sat for the same PEEE and DE Sessional Examinations at the end of the year.

Findings and Learning

Lesson Structure

Grouping of Modules
Both students and teaching staff found the grouping of the 3 modules meaningful. In particular, the linking of Project 1 to PEEE and DE was very welcomed as this gave students the opportunity to put what they learnt in theory into a practical project. Staff also found that they could bring out salient points regarding the practice of engineering that would otherwise not possible or difficult in a theory-only lesson. E.g. students quickly became aware that circuits that they designed on paper often did not work exactly as expected in real life. They also became acutely aware that not all components they desired were readily available, and that they often had to come up with alternative designs based on available components.

Project 1 as an Anchor
Many students found working on the project (especially the first project) a frustrating experience. This was primarily because they lacked the necessary skills at the onset to do a good project. They were expected to hone them through the project itself. The skills involved included project planning, being systematic and critical in their approach, and the ability to solder and troubleshoot well. As a result, many mistakes were made in the project fabrication process and this led to a lot of re-fabrication. This was time consuming and frustrating for students.

However, the amount of authentic learning that was taking place was great. Not only did students become more skilful after the project, the satisfaction of getting a project that they designed themselves working was also immense. They also became very careful not to repeat the same mistakes in subsequent project work. Many students had commented that they were quite proud of their achievements in Project 1. It showed them how much learning had taken place over a relatively short amount of time. They were keen to take their projects home to show it off to their friends and family members.

Reduction of Contact Time and Introduction of Independent Learning Time
There was initial resistance by students that they had to cover material on their own. It was also challenging to get them to realize that the material they covered themselves independently could be just as important as material that were formally taught in face-to-face lessons. These difficulties were, however, overcome by telling students explicitly at the beginning of the

academic year that their contact hours were in fact reduced. And in return they would have to do their part in learning some things on their own.

Many staff were also initially wary about not covering key material during contact time. However, the presence of activities and assessments that ensured that students learnt adequately help allay some of these fears.

It had been advocated that the pre-requisites for successful Independent Learning was a supportive environment that encouraged students' motivation, self confidence, curiosity and desire to learn. A climate that is sensitive, flexible and responsive to the learners' needs also had to be present [4]. Not all teaching staff found this easy to achieve. This was mainly because the skill set required for this was quite different compared to those required to conduct a traditional lecture. More training would be needed to bridge the competency gap.

L/T/P hours combined, 4-hour sessions

The response from both staff and students to this feature was mixed. Most found practical sessions that immediately followed a lecture type lesson useful in reinforcing concepts taught. Feedback was much better when a fully blended teaching session was designed and delivered over the 4 hours. But this type of lesson takes a lot of time and effort to create, and fully blended lessons only took place occasionally. More work will have to be done to take better advantage of this feature.

Some weaker students also found the 4-hour sessions daunting. A handful of them started to come in as much as 1 hour late for lessons towards the end of the academic year.

Teaching and Learning

Same staff teaching all 3 modules

Both students and staff liked this feature in the IP. In particular, the Master-Disciple aspect was well appreciated. The most common compliment given by staff teaching the IP was that they were able to coach students more closely, and in the process develop strong bonds with them. They also liked the fact that they were able to handle all aspects (components) of the modules taught, and that were able to link what is taught between modules.

Students also liked this arrangement as long as they were able to connect well with the staff teaching them. It would have been very difficult for them if they could not relate to the teaching staff. For this feature to work well, only the better lecturers should be assigned to the IP.

Another potential problem with this arrangement was that staff taking on the program for the first time would have to be familiar with all 3 modules instead of just 1. We mitigated it somewhat by selecting staff who were already familiar with at least 1 of the 3 modules.

Teaching done in Labs

This feature was also welcomed by both students and staff. However, in practice, this arrangement was administratively the most problematic one. Lab resources are precious to the school, and tying them down whether they are used or not in the name of flexibility was difficult

to sell to the management. It will also be the bottleneck should we decide to scale this structure up and apply IP to the whole school.

Although this is quite a key requirement in the IP, it was decided that we would have to relax this if necessary. As a compromise, we are prepared to have a 2-hour teaching session scheduled in a classroom followed immediately by a 2-hour session scheduled in the lab. In essence, teaching will still be done in 4-hour blocks, but the venue will be changed midway

PEEE / DE taught in alternate 3 to 4 week blocks

Informal oral feedback conducted with the students seemed to suggest that they preferred the concentrated approach as prescribed. A common comment made by the students was that they preferred this approach because their time was less divided.

While this view has its merits, it was felt by staff that this approach favoured the academically stronger as well as the more disciplined students. These students will be the ones who can keep up to date with their studies, and do assignments and tutorials prescribed in a timely manner. The intensity resulting from covering a lot of new material in one module in a short space of time may not be so suitable for weaker students who need more time to digest concepts taught.

This was especially so when basic material covered became pre-requisite knowledge for more advanced material to be taught. Often weaker students would still be struggling to grasp the basic concepts when more complex material was already scheduled to be taught.

Another potential problem with this approach was that students would miss a significant chunk of 1 module should they be absent for whatever reason for a stretch of time. They would find it very difficult to catch up on the lessons.

The benefits of this feature in IP were mixed, and further study would be needed to decide if this would be adopted in future.

Assessment and Evaluation

Formative Quizzes

Although potentially useful as a learning tool, it was found that many students did not take the quizzes seriously. This was probably because they carried no assessment weightage. Students who did, however, found that the quizzes gave useful feedback about their learning. Despite its shortcomings, the quizzes nevertheless gave the teaching staff a rough gauge of how the class was doing midway through a teaching block.

Continual Assessment

Conducting a formal test soon after covering a significant block of each module was a double edged sword. Students who could cope with the pace of teaching did well. Those who struggled to keep pace did not have sufficient time to sort out their difficulties before the test was due. This could be mitigated by moving the assessments further away from the end of the teaching block.

Another potential difficulty that may arise was that special arrangements needed to be made for a common test time slot to be available so that all the students could sit for the papers at the same

time. This did not pose problems during the pilot run of IP because the cohort size of DBE was only 4 classes. In the second run when IP was offered to an additional 8 DASE classes, the logistics of organizing such a test became formidable. As a result, a compromise was made.

The practical tests were still held soon after the teaching block was completed. But the common written paper was deferred to the Mid-Semester Test week (week 9 of a 15 week semester). This resulted in more acceptable results from the students in the second run.

Common Sessional Examinations

The results obtained from the common sessional examinations showed that DBE students who went through the IP did better in both modules compared to their peers in DASE and DEEE course who did not (see Tables 1 & 2).

COHORT	DBE	DEEE	DASE
COP	15	15	13
>= 80	**39.0%**	**25.2%**	**33.8%**
70-79	**23.2%**	**24.3%**	**26.1%**
60-69	**14.6%**	**18.9%**	**20.4%**
50-59	**12.2%**	**15.3%**	**7.6%**
< 50	**11.0%**	**16.2%**	**12.1%**
Mean	72.03	66.54	71.81
Max	**100**	**100**	**98**
Min	**35**	**9**	**22**

Table 1: AY0506 Sessional Exam Performance in PEEE (DBE in IP)

COHORT	DBE	DEEE	DASE
COP	15	15	13
>= 80	**54.9%**	**49.8%**	**48.4%**
70-79	**23.2%**	**26.7%**	**25.2%**
60-69	**13.4%**	**13.4%**	**14.2%**
50-59	**4.9%**	**3.2%**	**6.5%**
< 50	**3.7%**	**6.9%**	**5.8%**
Mean	78	76.5	76.6
Max	**98**	**99**	**99**
Min	**39**	**10**	**39**

Table 2: AY0506 Sessional Exam Performance in DE (DBE in IP)

It is important to take note of the different cut-off-points (COP) of the students in each cohort. The tables show that despite having a relatively weaker intake compared to DASE, DBE students outperformed them marginally.

In the second run of IP, the results were more inconclusive (see Table 3 & 4). While DASE outperformed the other cohorts as expected (given the better quality of students there), DBE did slightly worse than DEEE. However, both IP cohorts did better than DECC.

COHORT	DASE	DBE	DEEE	DECC
COP	14	18	18	22
>= 80	**54.7%**	**46.1%**	**51.5%**	**37.1%**
70-79	**22.0%**	**23.7%**	**22.0%**	**15.0%**
60-69	**13.8%**	**13.2%**	**13.4%**	**20.8%**
50-59	**5.7%**	**13.2%**	**8.2%**	**13.3%**
< 50	**3.8%**	**3.9%**	**4.8%**	**13.8%**
Mean	78.46	75.83	77.60	69.93
Max	**99**	**100**	**100**	**100**
Min	**33**	**30**	**32**	**2**

Table 3: AY0607 Sessional Exam Performance in PEEE (DASE & DBE in IP)

Cohort	DASE	DBE	DEEE	DECC
COP	14	18	18	22
>= 80	**40.3%**	**32.9%**	**37.0%**	**27.8%**
70-79	**21.4%**	**28.9%**	**19.9%**	**23.2%**
60-69	**14.5%**	**10.5%**	**18.8%**	**14.3%**
50-59	**15.1%**	**13.2%**	**12.0%**	**13.9%**
< 50	**8.8%**	**14.5%**	**12.3%**	**20.7%**
Mean	71.87	70.17	70.57	66.80
Max	**100**	**97**	**100**	**100**
Min	**11**	**28**	**15**	**9**

Table 4: AY0607 Sessional Exam Performance in DE (DASE & DBE in IP)

These mixed results could be due to the recruitment of new teaching staff into the IP in AY0607. They would be unfamiliar with some subject matter as well as the different approach taken in IP.

Unlike staff teaching IP in AY0506, they would also not have been involved in designing the program.

This view can be validated by studying the results of the 3rd run of IP in AY0708. Teaching staff would then be more experienced.

Conclusion

The Integrated Program was introduced as a way of removing many of the shortcomings present in the more traditional L/T/P format of teaching. With the IP, lessons were taught in labs by the same teaching staff over longer stretches of time. The same staff also taught the same students more than 1 module, including a Project module. As a result, lessons with more authentic problem solving can now be conducted. Linkages between different modules can also be more easily highlighted. And a substantial project can be used to anchor learning that would otherwise be abstract. Both staff and students who participated in the pilot run had found the program helpful. While some minor adjustments would be needed to address its shortcomings, the Integrated Program is a significant improvement from the teaching structure it replaces.

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