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Learning How to Learn Medical Signal Processing: a Case Study*

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Elements of modern teaching and learning environments such as Active Collaborative Learning (ACL) and Project Based Learning (PBL) are being widely adopted in universities as powerful teaching tools. By design, these tools require the actual immersion of students in learning activities. Furthermore, they emphasize the key responsibilities students have to assume towards their own education. While the majority of universities are taking efforts to train teachers to fulfill teachers' roles, it is rare to find universities where students are trained to fulfill theirs. In this paper we report our experience in designing a course on Biomedical Signal processing based on the concepts of action leaning in an ACL/PBL framework. In particular, we investigate the importance of formally educating our students on modern best practices of university education. Our results indicate the importance of such training and supports the hypothesis that training students on how to learn is an important, but often underemphasized phenomenon.

Keywords: signal processing; learning to learn

INTRODUCTION

BIOMEDICAL SIGNAL PROCESSING (BSP) as a subject is inherently multidisciplinary in nature. It requires, as prerequisites, a sound understanding of Digital Signal Processing (DSP) theory, mathematics, basics of medical instrumentation and electronics. The wide scope of BSP and its associated prerequisites make it a challenging task to teach and learn in the university.

In a traditional approach, basic concepts of DSP are covered through lectures typically conducted in transmission-mode. It is not uncommon to find courses where in-class lectures, tutorials and exams constitute the only modes of course/learning activities. In some courses, students are given laboratory computer projects, where they implement DSP algorithms covered in lectures. Biomedical data for these projects can be synthetic and/or real-world signals, often directly supplied by lecturers.

One of the drawbacks of this model is that epistemological aspects are missing from the learning environment, and there may be little motivation for students to learn the myriad of new concepts and math-heavy lecture materials. The lack of 'immersion' aspects aggravates the problem of student disengagement and hinders the process of active learning. For BSP, the immersion experience is a necessity, rather than a convenience. However, one of the problems a teacher has to face in introducing students to a realistic environment is that the difficulty of getting them into a suitable clinical environment which allows sufficient hands-on learning flexibility [1].

Elements of modern education techniques such as Active Learning (AL), Collaborative Learning (CL) and Problem Based Learning (PBL) are currently being widely adopted in universities as powerful teaching tools. BSP is well suited for implementation within those frameworks [2–4], and several groups around the world have started exploring the technique recently [e.g.: 1–4], [5]. In [6] Malicky et.al. have systematically documented various pedagogical methods available to an engineering educator, and developed a method to choose and achieve best practice by using a decision matrix approach. The method attempts to balance various (sometimes conflicting) situational factors that exist in the particular teaching environment.

By design, techniques such as ACL/PBL and their combinations require the active engagement (and immersion) of students in learning activities. All of these techniques emphasize the key responsibilities students have to assume towards their own education. While the vast majority of universities are taking great efforts to train their teachers to fulfill teachers' roles, it is rare to find universities where students are trained to fulfill theirs. However, a small minority of engineering educators [5, 7] has recognized the fundamental need for formally empowering students to learn how to learn, as a way of creating an ambience for education in the 21st century.

In our opinion, this is a significant shortcoming, which needs to be addressed urgently and decisively.

Student (un)preparedness for action learning?

By the time students reach the university, they have been thoroughly exposed to traditional trans-

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mission-mode teaching within the primary and secondary education systems. It is our observation that only a few students are initially aware of the notion of action learning or comfortable with the responsibilities coming towards them in the process of their own education. Felder succinctly and dramatically summarises this point as follows [8]:

> . . . and most of them hate being held responsible for material I have not explicitly covered in lectures. They always counted on their teachers to tell them everything they needed to know for the exam . . . I welcome these students to the future life. When they go out into the real world there will be no teachers, no lecturers no example problems with worked out solutions.

It is not difficult to envisage that if students are unaware of their responsibilities and/or are underprepared to meet them, action learning will not succeed. The primary reason would be that student expectations would diverge from actual learning requirements leading to student disengagement and resentment.

It is of interest to investigate how these attitudes translate into student evaluation of the 'learning outcomes' and the 'teacher', through traditional instruments such as institutional Teaching Evaluations (TEVAL).

Coupled invariably with the processes of education are the student expectation of learning outcomes, and the perceived quality of care. The issue of measuring learning outcomes, or the quality of education, is a difficult one to fathom. Barnett's notions of the super-complex world [9] and the uncertainties associated with the future explain why it is extremely difficult for universities (even with ready access to the collective experience of its faculty) to design curricula that are guaranteed to be relevant into the future.

Individual students lacking wide experience should find it a formidable task to judge the ultimate value of the learning outcomes, at their first encounter with a particular subject [10–12]. Furthermore, students who are ignorant of the best practices of teaching/learning are unlikely to appreciate environments such as ACL and PBL, which places extra burdens on them. This can lead to student disengagement and much reduced learning outcomes.

What students perceive as the quality of the education they receive, and more importantly, their expectations of learning processes have become factors of pivotal importance driving the direction of tertiary education. It is imperative that we educate students on the fundamentals of learning techniques such that they gain some awareness of the best practices of teaching. This should enable them to identify and appreciate such practices, even if it shifts more responsibilities towards students!

Thus, we see a serious danger in not educating our students about the processes of education and not studying their notions of best-practices in teaching. While the vast majority of universities are taking efforts to train their teachers to fulfill teachers' roles, it is rare to find universities where students are trained to fulfill theirs. The fundamental irony of this situation is that techniques leading to deeper learning outcomes depend inherently on active student engagement, and both students as well as teachers are required to be trained in order to have success.

Scope and the novelty

We investigated how important it is to educate students about the current understanding of teaching and learning processes, before teaching a course on Biomedical Signal Processing (to be taught using the ACL framework.

Techniques such as ACL are not widely used in such teaching, even though the subject is well suited for implementation within those frameworks.

METHOD

Context for case study

The University of Queensland (UQ) designed a new graduate level course on Biomedical Signal Processing (ELEC7902). The course was designed from scratch, allowing us the maximum flexibility to incorporate modern techniques of teaching and learning with a view towards maximizing learning outcomes for the students.

One limitation of the study was that the student enrollment number was low (six students; one student withheld permission to use data for research purposes), making statistical analyses meaningless. Since this was the first time the course was offered, no data from previous years were available for comparisons.

For these reasons, we resort to an in-depth case study approach rather than statistical methods.

Brief description of course

The purpose of ELEC7902 was to introduce students to the important aspects of signal processing as applicable in medical instrument design and clinical diagnosis. ELEC7902 would provide opportunities to acquire in-depth knowledge in important aspects of the practice of biomedical signal processing, through a series of focused project activities on real-world signals. Opportunities would be provided to acquire independent learning skills via directed reading of subject matter.

The course consisted of several Modules, named Module-A to Module-E. The modules were designed as independent units and were taught by different lecturers. The author taught Module-A to Module-C.

- Module-A Learning How to Learn [13]**:** schematic overview of teaching and learning models (transmission, constructivist, social construc-

tion); approaches to learning (deep and superficial), environments conducive for deep learning/active learning (ACL, PBL, etc). What to expect in ELEC7902? Nature of the course; student responsibilities.
- Module-B [14] Polysomnography Signals (lectures, discussion and computer labs): Polysomnography signals: clinical uses, acquisition and processing. Linear/nonlinear modeling with application to artifact detection and signal prediction.
- Module-C Music and Physiological Signals (project-based learning): music, relaxation and physiological signals (Signal Processing Challenge). Experiment design, instrumentation, laboratory-based signal acquisition, computer laboratory-based digital filtering and EEG decomposition.
- Module-D ABR reconstruction and objective detection (lectures and computer labs): Auditory Brainstem Response (ABR): physiology, acquisition and signal processing.
- Module-E Virtual Microscopy: image acquisition and storage (project-based learning): introduction to clinical applications of virtual microscopy; slide scanning and acquisition; image mosaicing (stitching); color imaging; image storage using JPEG 2000; image browsing using JPEG Internet Protocol (JPIP).

Learning activities associated with Module-A are outlined in Section A of the Appendix.

Tools for measuring outcomes

Learning outcomes were assessed using several objective instruments used routinely in case studies.

- Pre-course Mini-Survey (PMS): at the beginning of the course, a mini-survey was administered to students. The PMS sought to explore how they felt about their level of knowledge at the beginning of the course. More importantly for this paper, the survey had the following two free-response type questions:
  i. Have you ever been taught how to learn (or how to improve your learning skills)?
  ii. Do you think there is any need for an individual to start learning how to learn?
- End-of-Module Assessment (EOA): at the end of each learning module (except Module-A) a quiz was administered. In Module-A, students were required to read a lecturer-supplied research article on 'learning' and write a 500–700 word critique for assessment. The summary was presented in the class and defended by each student. This activity was also used as a basis for peer-to-peer learning.
- End-of-Module Project Assessment: at the end of each module (except Module-A which did not have a laboratory project) students were assessed as follows: student groups were required to submit one collaborative group report and demonstrate a functioning solution to the problems posed in the hands-on component of a particular module.
- (Blackboard® Discussion Board Postings: ELEC7902 used the Blackboard® as the course management software. Active participation in online Discussion Board constituted a part of assessable activities of the course. Throughout the semester, Discussion Board activities were monitored to gauge student motivation, engagement and aspects of collaborative learning.
- Comprehensive Student Feedback Survey (CSFS): a comprehensive feedback survey was conducted in the last week of classes, after completion of all teaching/learning activities associated with Modules A, B and C.
- University of Queensland Institutional Teaching Evaluation (TEVAL): UQ requires that all teachers administer a teaching quality evaluation survey (TEVAL) every time a subject is taught. The TEVAL is managed by the Teaching and Educational Development Institute (TEDI), University of Queensland.
- Personal observations: while teaching, students were observed in the lecture rooms, medical instrumentation laboratory and computer laboratory. We provided each student with detailed customized feedback after every assessment, which also served as a form of documented observation. Students were then encouraged to present their reflections on the lecturer's feedback and general learning outcomes.

RESULTS AND DISCUSSION

Student perception on the need to learn learning methods

In the Pre-course Mini-Survey (PMS) we questioned students on the need to learn how-to-learn. Student responses (roman numerals indicate student identifiers) are reproduced in verbatim below:

(1) Have you ever been taught how to learn (or how to improve your learning skills)?
  (i) 'Yes, in some seminars'
  (ii) 'No'
  (iii) 'Yes, in year 12 I went to a seminar on learning'
  (iv) 'I have never been taught how to learn, but yes when I go wrong I have received guidance on how to rectify my mistake'
  (v) 'Yes, but not in engineering—only in volleyball'.
(2) Do you think there is any need for an individual to start learning how to learn?
  (i) 'Yes, sometimes, if the approach being used is wrong'
  (ii) 'Not sure, simply I've never come across a situation where students are taught directly how to learn'

(iii) 'Yes, it provides a more efficient method of understanding topics'
(iv) 'No'
(v) 'Yes, but different learning methods are suited to different disciplines. Also this may not be necessary if teachers are very good at putting students in situations where they must learn'.

From the student responses, it is clear that none of the students had received a formal introduction to learning at the tertiary level, even though some had attended seminars which were not directly integrated with their academic work. The student attitude towards the need for learning how-to-learn is generally positive, with four students expressing non-negative opinions. Note that student (iv) has strongly rejected the idea of learning how to learn.

Student perception during and at end of semester

At the end of the semester we questioned the students on Module-A via our CSFS survey. Free response questions relevant to Module-A and corresponding student answers are reproduced below.

(1) What did you like the best about module Learning How to Learn?
   (i) 'It was very general and simple and short. No pressure'
   (ii) 'Realizing the learning method I have been using all my life unfortunately was not the best method around. I had many difficulties in the pass [past] not being able to understand why other peers in the same class could gain so much more knowledge and understanding than I could. After this module, I have not only learn and understand more about myself, the best thing is to realize my pitfall in [is] my lack of deep learning'
   (iii) 'It illustrated in a clean manner how people learn'
   (iv) 'A good introduction of techniques to be applied'
   (v) 'Interesting, applicable topic (to our other coursework)', 'new idea to me', 'a great chance to discuss own ideas with class lecturer both on-line and in class'
(2) What did you like least about the module Learning How to Learn?
   (i) 'Not much significance, I think'
   (ii) 'Nothing in particular'
   (iii) 'It was very general'
   (iv) 'The time period'
   (v) 'The activities suggested (and assessment description) in the course guide didn't seem to match up with instructions in class'

The free responses indicate a general positive shift of opinion about the benefits of learning how to obtain an education. While student (iv) seems to have developed a positive attitude towards the module, student (i) appears to discount the significance of learning-to-learn. Student (ii) reports a dramatic outcome, beyond our expectations.

Table 1. CSFS Survey: Student feedback on learning activities (see Section A, Appendix) of the module Learning How to Learn (Module-A) activities (scale 0-10)

	Score						
Student #	a	b	c	d	e	f	Mean
i	9	8	8	8	6	6	7.5
ii	10	10	8	10	10	10	9.7
iii	8	7	6	7	7	8	7.2
iv	6	5	5	7	6	6	5.8
v	5	5	7	8	6	6	6.2
Mean	7.6	7.0	6.8	8.0	7.0	7.2	7.3

The CSFS survey also explored student opinion on the learning activities listed in Section A of the Appendix. A numerical scale from 0–10 (0 representing the lowest and 10 representing the highest score) was used to score the value of each activity. The results are shown in Table 1. Because of the small size of the class, we will not attempt to provide detailed statistics of the numerical responses, because of the high variance that can render a statistical report meaningless.

Student (iv), who strongly stated that there was no need to learn how to learn (PMS survey) had the poorest opinion of the usefulness of overall course activities (mean = 5.8; lowest sub-scores of 5 are for activities directly addressed core subject matter). On the other hand, Student (ii) who had no prior exposure to teaching/learning methods and expressed dramatic outcomes returned a mean score of 9.7.

Student (v), while scoring the Module-A learning activities at a mean rate of 6.2, provided more detailed reflections via the Blackboard Discussion forum:

> I think that the learning to learn module was invaluable for my learning throughout this course, and I'm sure it will assist my learning for the rest of my life.
>
> After reading some articles, and going through the first module I believe that ACL/PBL have encouraged me to take a deep learning approach in some previous courses. This has had a substantial impact on both my results in these courses and also my enjoyment of the courses, and hence my choice of direction and specialisation in my degree.
>
> I am interested to consider how these concepts apply to 'non-academic' learning, i.e. techniques in sport (e.g. a tennis serve), music and language (esp. vocabulary). I have found that in these areas the 'transmission' learning model is unavoidable.

These observations are confirmed again by the CSFS survey question items and student responses (see Table 1 above and Table 2 below). The statement: 'Module-A encouraged deep learning' received a student rating of 10, 10, 10, 4, 8, 10 indicating the strong influence it had on the students. However, Student (iv), who saw no

Table 2. CSFS survey continued: student feedback on Module-A (scale 0-10)

Student Number	encouragement of deep learning	Opportunities for collaborative learning	Facilitation of independent learning	Fostering student generated activities outside class	Development of life-long learning skills	Level of engagement experienced with the module	Satisfactoriness of the overall learning outcomes	Having Module-A was a very good idea?
i	10	5	10	9	10	9	10	2
ii	10	5	10	7	10	10	10	10
iii	8	7	5	8	3	4	7	7
iv	4	6	8	7	6	7	5	4
v	10	5	10	9	10	9	10	10
Mean	8.4	5.6	8.6	8.0	7.8	7.8	8.4	6.6

need to learn how to learn at the beginning of the semester, supported that assertion only at 4. The statement 'Satisfactoriness of the overall learning outcomes' received support at 10, 10, 10, 5 and 7. Student responses to the assertion 'Having Module A was a very good idea' ranged from strong to weak (10, 7, 10, 4, and 2).

Queries on 'facilitation of independent learning', 'fostering student generated learning activities outside class' and 'development of life long learning skills' all received high ratings (means of 8. 6, 8, and 7.8). Note that all of these three characteristics are directly or indirectly associated with Action Learning. The weakest response was received for the query 'opportunities for collaborative learning' (mean = 5.6). Module-A indeed was weaker in that aspect, and most of the collaborative mode of learning was targeted towards the core of the subject as contained in Module-B to Module-E.

In the independent teacher evaluation (TEVAL) of the University, student responses to item number Q15 ('I have developed a good understanding on teaching and learning issues') established that all students agreed with that assertion (score 4.21/5). The TEVAL survey is based on the lecturer's performance throughout the whole course. For that reason, scores on other more generic TEVAL items are not very useful in a focused discussion of Module-A as we describe in this paper. However, we think it is useful to mention that the students rated the overall effectiveness of the teacher at 4.62/5.

In our observations, Module-A on Learning How-to-Learn made a dramatic difference to the course in several ways. It provided us with an excellent opportunity to introduce students to modern methods of learning and teaching, and direct them towards deep learning. The Course Guide and reading material provided to students enabled them to explore more on learning techniques. It also alerted them to the issue of difficulties in preparing for an unknown future in the sense of Barnett [6] and Lucky [2]. At the end of the module, students were aware of concept such as transmission mode, constructivist, social constructivist, deep learning approach, active learning, ACL/PBL and the like.

Table 3. The number of Blackboard Discussion Board postings for each module

Module	Total # Postings	# students active in the discussion
Module-A	10	3
Module-B	13	4
Module-C	53	6

Module-A alerted students towards what to expect in other modules of the course, and how to make the maximum benefit from them (not to complain at the first opportunity when the lecturer shifts part of the learning responsibility to students!). The adverse student reactions to ACL/PBL as described in Section 1.1 (Felder) were not observed in ELEC7902.

In our personal observation, almost all students approached Module-A with an open mind, even though the contents were a novelty for them in their tertiary education. One student (Student (iv) had negative opinions about the usefulness of Module-A leading to a reduced engagement with learning activities. Module-A generated fewer (out of the class) peer-to-peer interactions as seen from Table 3 (Blackboard postings).

We saw that Module A made a significant impact on the students and enabled them to engage in the activities of other modules, which had a variety of activities requiring various levels of active engagement of students.

In the past, universities followed an elitist-approach to education, in which only a limited number of the 'best-among-the-best prepared' students were admitted to tertiary programs. At present, however, many universities around the world are shedding this model in favor of a mass-education approach, keeping up with the realities of financial, political and industry constraints/requirements of the times. In a typical university class, it is now common to see students with a vast range of background preparation, skills and expectations. All of these students demand the 'best-practice' services from the lecturers and the universities, according to their individual perceptions of what this 'best-practice' is.

Partly in response to this situation, and also in part aiming to benefit from the availability of a better understanding of the processes of education, universities are investing heavily in improving their teaching/learning environments. The approaches often take the forms of:

- training of the faculty in improving the effectiveness of teaching
- upgrading facilities such as lecture theatres, laboratories
- providing enhanced access to the Internet and associated learning opportunities.

While these are all worthy efforts, their ultimate success depends, we believe, on formally preparing our students in the processes of education as practiced in a modern university.

CONCLUSION

The results of our investigation led to the conclusion that it was beneficial to formally educate students with modern concepts of teaching and learning, before actually implementing methods such as ACL/PBL in the class. In the absence of such training, students will not be fully prepared to shoulder the additional responsibilities that fall upon them leading to resentment and eventual disengagement from the learning process. However, one of the main challenges is to make sure every student in the class appreciates the true worth of spending some time closely examining teaching and learning models as used in a modern university. Some students who do not see any value in that may disengage from the whole process.

The general validity of our results in this study should be further tested in a large class setting.

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APPENDIX

(A) Module-A learning activities:

(a) Student Mini-Survey on Learning/Teaching.

(b) Classroom-based, active mode, Round-Table Discussions on:
- Schematic Overview of Learning (Transmission, Constructivist and Social Constructivist Models)
- Different Approaches to learning (deep, superficial)
- Deep learning environment (ACL, PBL, Case Studies etc.)

(c) Reading Assignment
- Read and Critique a research paper on teaching/learning
- A 500-700 word summary of the paper
- Class Presentation and defense of the summary.

(d) Collaborative/Cooperative Learning
- peer learning in the class via discussions
- peer-to-peer learning outside the class

(e) General Activities
- Participation in class discussions
- Blackboard Discussion Board
- Tasks outlined in the Module Guide provided to the students (reading targeted literature; answering questions, reflections and formulation of ideas)

(f) Assessment items
- Reading assignment and class presentation.

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