# Introducing the balanced classroom: Applying *systems thinking* to systems engineering education

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**Abstract.** According to the literature, previous research on systems engineering education and curriculum design focused on the nature of the knowledge to be taught, and tended to ignore pedagogical issues. This paper:

- Presents some of the results of research and development into both the knowledge requirements for, and pedagogy of, teaching and learning in postgraduate classes in systems engineering, project management and innovation management, lasting from 1998 to 2015.
- Focuses only on the pedagogy.
- Suggests that instead of adopting a single technique such as the "Flipped Classroom" an Authentic Learning Environment or games/simulations, a number of teaching techniques (subsystems) should be used together in an interdependent manner blending them to enhance the learning experience in the classroom (the system).
- Describes a balanced classroom, a system which mixes a number of previously tested teaching and learning subsystems in a synergistic manner for the first time.
- Shows that delivery mode does not seem to make a difference.
- Concludes with a brief summary of the results of using the balanced classroom in three different classes at the National University of Singapore (NUS) in 2013 and 2014.

The contributions of the balanced classroom to teaching and learning are:

1. It is the first time that all the subsystems have been used (integrated) together interdependently as a system.
2. It overcomes the major defects in the "Flipped Classroom".
3. It maps into the Impresario model (Weston, 2015) as discussed in Section 11.
4. It documents the experiences of trying innovative teaching approaches and provides examples of the use of different components and corresponding student reactions.

***Keywords***: systems engineering education, systems integration, balanced classroom, problem-based learning, flipped classroom, activity based learning, authentic assessments, an Authentic Learning Environment.

## 1 Introduction

"*The purpose of systems engineering education is to shorten the time needed to become a systems engineer. In the past, engineers became systems engineers*[1] *after 10-25 years of practical experience. The challenge is to shorten this to 5-10 years*" *5-10 years*" (Enger, 2012). This paper:

[1] Lead or Chief systems engineers who can supervise and mentor junior systems engineers working on complex projects.

1. Discusses a part of applying systems engineering to the problem of optimising postgraduate education pedagogy to meet Enger's challenge for part-time mature students.
2. Focuses on pedagogy not the knowledge being taught.

This applied research began in 1996 after the author transitioned from a career as a systems engineer and project manager into a career in postgraduate education in academia. The author soon recognised that there was a difference between the traditional full time students and the part-time postgraduate students taking time out of their busy work and family lives to pursue continuing education. The part-time students had less time to invest in their learning so their learning needed to be more effective[2] which led to the following research questions:

1. What factors make learning effective?
2. How can those factors be incorporated into a postgraduate classroom environment?

Accordingly, Section 2 introduces the context for the research. Section 4 summarises the research and development leading up to the balanced classroom. Section 5 summarizes some of the requirements for the balanced classroom developed during the research. Section 6 describes the architecture of, and subsystems in, the balanced classroom. Section 7 outlines how the balanced classroom is used covering the three parts of each session. Section 8 shows how the three types of content free knowledge are incorporated into the balanced classroom. Section 9 shares some of the results using the balanced classroom in three different classes at NUS in 2013 and 2014. Section 10 contains some reflections and comments, while Section 11 discusses possible avenues of future research. Section 12 summarises the paper. Section 13 contains some conclusions. The contributions of the paper on the balanced classroom to the scholarship of teaching and learning are:

1. It is the first time that all the subsystems have been used (integrated) together interdependently as a system.
2. It overcomes the major defects in the "Flipped Classroom".
3. It maps into the Impresario model (Weston, 2015) .
4. It provides examples of the use of different components and corresponding student reactions.
5. It shows that delivery mode does not seem to make a difference.

## 2 The context

The author's perceptions of postgraduate education as a Doctoral student 1987 to 1997 and later as a Graduate Teaching Assistant at The George Washington University (GWU) and as a program director sitting in the first session of different courses at University of Maryland University College (UMUC) from 1997 to 1999 was that the curriculum and pedagogy were subjective. In the language of systems engineering, the curriculum defines the learning outcomes or the requirements; the pedagogy is how the knowledge is taught in a system created by the teacher that comprises knowledge, the teaching and learning processes and the teacher and students.

Classes on systems engineering and computer systems management at both GWU and UMUC were constructed about the curriculum: one or more textbooks and a single paragraph description of the knowledge content of the course. The teachers had the academic freedom to adjust the details of the curriculum based on their interpretation of what the students needed to know (the subject matter topics they emphasized, ignored or added) and to use any

[2] This does not imply that traditional learning does not need to be effective.

teaching style they wished as long as the students did not complain[3,4]. At that time, most instructors still lectured using the whiteboard and overhead projectors, some were innovative and used PowerPoint, some added in-class exercises and a few even ignored the prescribed and often expensive textbook. Accordingly, a course with a given nominal curriculum, e.g., SYS0101, taught by two different teachers in the same semester in two different locations[5] (face-to-face or online) could be very different in what was taught, how it was taught and how it was graded[6].

The starting point for the research was the typical experience-based class. After much reflection of the author's classes and others he audited as a program director and interested participant, in general the knowledge content of a class was based on a combination of:

1. A textbook based on the author's knowledge and experience, in most cases written from a single perspective.
2. The instructor's experience as a practitioner[7] which augmented the text book.
3. Occasional readings from conference papers and other textbooks.

The content was generally stand-alone in that it lacked the anchor points to existing knowledge in other classes in the degree program and did not place the knowledge in context. As a result, the author's impression was that the learning experience was less than it could be, namely:

- Students who understood the topic at the start of the class, understood it better at the end of the class.
- Students who didn't understand the topic at the start of the class, didn't understand it less at the end of the class.

And it was this undesirable situation that prompted the research into increasing the effectiveness of postgraduate teaching and learning in systems engineering.

## 3 The research questions

The first research question was "*What factors make learning effective?*" is discussed in Section 4.1. The second research question was "*How can those factors be incorporated into a postgraduate classroom environment?*"

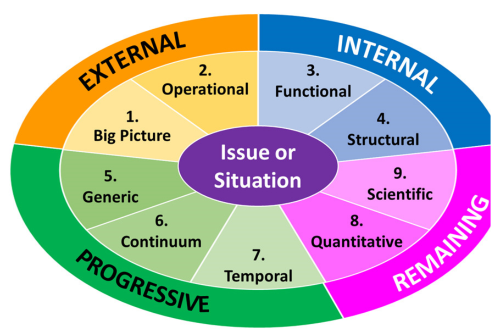


***Figure 1 The Holistic Thinking Perspectives***

The first step in applying systems engineering to the problem was to gain an understanding of the situation by observing the situation from multiple perspectives. The relevant findings are summarized herein sorted according to the Holistic Thinking Perspectives (HTP) (Kasser, 2013a) pages 90 - 110) shown in Figure 1.

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[3] As a Graduate Teaching Assistant, for his first postgraduate class, the author was handed a course description, and a text book and told not teach the contents of the textbook. He was then n his own.
[4] One professional who began to teach part time, taught his first class by reading aloud from the text book to the students. The students complained and author as program director had to correct the teaching style before the second session.
[5] Both universities offered multiple iterations of the same courses as evening classes at different locations in the Baltimore-Washington metropolitan area.
[6] As a student at GWU and having suffered through one teacher's course, the author chose to drive 40 miles each way between Silver Spring and Baltimore in the following semester to avoid taking the next course with the same teacher.
[7] For those classes where the instructor had work experience.

### 3.1 Big Picture Perspective

Perceptions from the *Big Picture* perspective include:

- Learning takes place in a classroom which is defined as a system consisting of students, instructor, technology and knowledge.
- The literature discusses the need to improve cognitive skills of systems engineers and project managers.
- There seemed to be a lack of systems thinking in the literature in that the literature contained either-or theories, advocated single teaching methods and separated learning from applying knowledge. The systems approach is to use multiple methods of teaching in a mixture so that each method compliments the other. Accordingly, the lecture and readings contain the knowledge and the students do exercises to both learn and apply the knowledge.

### 3.2 Operational Perspective

Perceptions from the *Operational* perspective indicate that in the evolving traditional classroom the lecturer lectures, the students apply the knowledge in the exercises and report their results. The Concept of Operations (CONOPS) for a typical traditional class session[8] can be described in a set of scenarios (SC) which include the following:

SC 1. The students read the session material individually before the session begins[9].
SC 2. A lecture by the instructor which summarises the readings highlighting the main points.
SC 3. Another lecture by the instructor which adds additional material pertinent to the knowledge covered in the session. This scenario often follows SC 2.
SC 4. A group exercise which the students perform in teams.
SC 5. A presentation of the outcomes of the exercise.
SC 6. A short discussion facilitated by the instructor.

SC 2 can take several formats including the following three:

1. The traditional synchronous face-to-face lecture in the classroom and a synchronous lecture in the online environment.
2. A pre-recorded lecture in the asynchronous online environment.
3. The flipped classroom (Bergmann and Sams, 2012) which is:
    - Generally based on using a pre-recorded video of the lecture in the synchronous face-to-face environment which is an incomplete implementation of inverted learning (FLN, 2014) .
    - A face-face classroom and a synchronous online classroom session in which the:
        a. Instructor pre-records the lecture and uploads it to the class web site.
        b. Students (are required to) view the lecture before the classroom session.

    Time saved by not lecturing in the classroom session is to be used for exercises and other participative activities. However, although the use of the flipped classroom has shown an improvement in learning, see Chao and similar for details (Chao, et al.,

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[8] This CONOPS applies to online classes as well as face-to-face ones in the classroom. Some scenarios may not be included in every class.

[9] An assumption for an ideal class, but in the real world students tend to avoid reading the materials unless they have to, presumably hoping that the teacher will cover enough of it in the lecture.

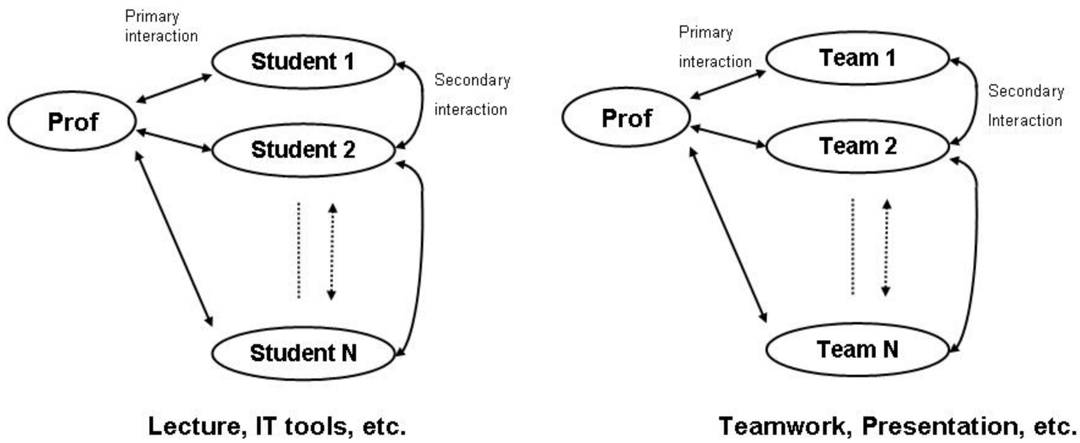


***Figure 2 Two of the relationships in the instructor-based classroom system***

2015), the pre-recorded lecture limited implementation of the flipped classroom is a non-systems approach to improving the learning environment, and suffers from at least three defects, namely:

1) Students cannot interrupt the asynchronous lecture with questions.
2) A pre-recoded video lecture is passive learning because it is still a lecture.
3) The flipped classroom is based on the incorrect assumption that all the students will view the lecture before class. Unfortunately, experience has shown that students treat the pre-recorded lecture in a similar manner to the way they treat the traditional readings; some read the material ahead of class and some do not, where:
    a. Good students interested in the topic do tend to view the lecture before the class.
    b. Poor students who need to view the lecture before class tend not to view the lecture before the class[10].
    c. Students who expect the instructor to tell them everything they need to know to pass the class in the classroom tend not to view the lecture before the class.

### 3.3 Functional Perspective

Perceptions from the *Functional* perspective identified a number of functions taking place in the *Operational* perspective scenarios including the following:

- Interactions between professor/instructor and students as shown in Figure 2 (Zhao, et al., 2009).
- Learning.
- Teaching.
- Reading.
- Writing.
- Talking.
- Thinking.

[10] Tested in practice by loading the lecture as PowerPoint slides and MP3 audio files. When instructions for the weekly exercises and assignments were inserted in the audio portion of the lecture some students did know about the instructions.

- Sleeping.
- Using the laptop computer for non-educational purposes[11].

### 3.4 Continuum perspective

Perceptions from the *Continuum* perspective include:

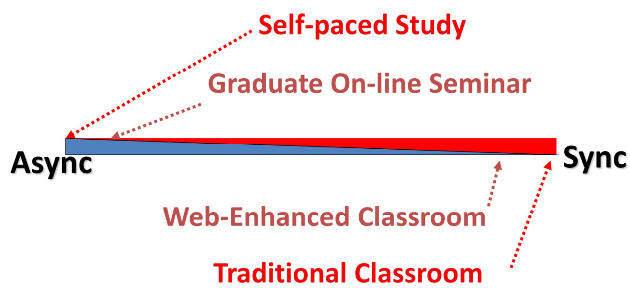


***Figure 3 The spectrum of syncronicity***

- The pedagogy of a class needs to take into account that the degree of learning by students varies according to the delivery method and individual learning style. For example, "*Students learn in many ways - by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing and drawing analogies and building mathematical models; steadily and in fits and starts. Teaching methods also vary. Some instructors lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasize memory and others understanding. How much a given student learns in a class is governed in part by that student's native ability and prior preparation but also by the compatibility of his or her learning style and the instructor's teaching style. Mismatches exist between common learning styles of engineering students and traditional teaching styles of engineering professors. In consequence, students become bored and inattentive in class, do poorly on tests, get discouraged about the courses, the curriculum, and themselves, and in some cases change to other curricula or drop out of school*" (Felder and Silverman, 1988).
- The Dale Cone and Learning Pyramid ignored learning styles and focused on different teaching/learning functions.
- Active and passive learning. Active learning was deemed to be better than better than passive learning. However, the meaning of the term 'active learning' covers a broad spectrum of team work exercises ranging from 20-minute problem solving exercises to the way in which postgraduate business schools tend to work, i.e., where a lecturer introduces a subject, sets the class a problem based in the subject, and the class then splits into their teams to work on the problem[12], perhaps for a week, finally presenting their solutions in competition at the end of the week.
- The large number of possible class delivery modes with various mixes of synchronous and asynchronous techniques. These classes are spread out along a continuum of possibilities, the spectrum of synchronicity shown in Figure 3. The traditional face-to-face classroom lies at the synchronous end of the spectrum. The traditional class can be augmented with a web page, a Listserver, and other synchronous and asynchronous techniques. When web augmentation takes place, the web augmented traditional classroom moves away from the edge of the synchronous end of the spectrum towards the centre. A face-to-face class that uses a web page for proving copies of handouts and readings to the students is not 100% synchronous. However, while the class is not 100% synchronous it is often referred to as a synchronous class.

  At the other end of the spectrum is the totally asynchronous class-room. This represents the self-paced studies, correspondence schools and other techniques in which there is no synchronous contact between anyone in the class. A graduate school semi-

[11] Such as emails and watching World Cup Soccer matches.
[12] Identifying the knowledge and applying it to solve the problem

nar that is mostly asynchronous does generally allow for synchronous student to instructor and student-to-student communications via the traditional telephone system or via a Voice over the Internet (VOIP) system. Therefore, while the graduate seminar is not 100% asynchronous, it has so many of the characteristics of an asynchronous class that it is often referred to as an asynchronous class.

### 3.5 Quantitative Perspective

Perceptions from the *Quantitative* perspective include:

- There did not seem to be any consistency in grading. Students were graded in different ways by different instructors. When different instructors taught the same course, one instructor could award an A grade for work that would receive a B- grade from a second instructor. Some instructors graded on activities or time spent on doing the exercise rather than on the output (content and logic), e.g. "well she put a lot of effort into the essay so she deserves an A".
- At that time, UMUC did not grade on a curve, it seemed that the instructors in easy classes, defined as students receiving high grades for what was in the author's opinion mediocre work, got higher evaluations than instructors of harder classes.

## 4 Summary of the research and development methodology

The iterative Systems Development Process (SDP) that produced the balanced classroom as a system that meets the requirements in Section 5 began in 1996. It transitioned from the initial lecture-centric classroom in both traditional face-to-face and online classrooms in a number of iterations. There was also one challenging class which contained one traditional face-to-face synchronous section at UMUC in Maryland combined with one asynchronous online section with an instructor in Adelaide, Australia (Kasser, 2001). This class is discussed in Section 4.10.

Except for one iteration of one class, the number of students in a class ranged from seven to 35. Although asynchronous pre-recorded lectures had been used in online classes since 1998, the first time the asynchronous pre-recorded lecture was used in a face-to-face class was in the first iteration of SDM5004 at NUS in 2011 where the student attendance was 70[13]. That asynchronous pre-recorded lecture in the face-to-face class was a solution to the problem of how to allow all student teams to make a presentation in the limited classroom time[14]. The major elements of the research and development included:

1. How students learn discussed in Section 4.1.
2. The process for crafting a degree or class discussed in Section 4.2.
3. The curriculum objectives discussed in Section 4.3.
4. Student attitudes discussed in Section 4.4.
5. The difference between synchronous and asynchronous lectures discussed in Section 4.5.
6. The different technology for recording the lectures discussed in Section 4.7.
7. The difference in teaching styles in a class on systems engineering in 2009 discussed in Section 4.8.
8. The development of the knowledge reading concept discussed in Section 4.9.

[13] Many of the students needed the required class to graduate that year and if they were precluded from the class they would have to wait a year to graduate. This would have been unfair so the instructor allowed them into the class and then had to redesign the pedagogy to cope with the large number of students.
[14] The solution was to move the lecture out of the classroom time.

9. The hybrid class containing a mixture of online and face-face components discussed in Section 4.10.
10. Introducing authentic learning into the classroom as discussed in Section 4.11.
11. Overcoming one of the defects in the flipped classroom lecture in Section 4.12.

Consider each of them.

### 4.1 How students learn

An understanding of how student learn is critical in order to design an optimal pedagogy. This insight prompted the first research question which was "*What factors make learning effective?*" Applying systems engineering to the problem of finding answers to the research question in 1997, the literature review in the domain of scholarship and learning identified the following factors that affected learning:

1. ***Two approaches to instructional design:*** objectivist and constructivist (Nuldén, 1997).
2. ***Different teaching methods:*** Mills discusses the way time should be allocated in the classroom based on data from providing training during World War II and presented the data shown in Figure 4 (Mills, 1953) page 39). the ***Dale*** Cone of Experience (Dale, 1954) and the Learning Pyramid developed in the 1960s at the National Training Laboratories, Bethel, Maine (Lowery, 2002), stated that listening to lectures was the worst way of learning while any of the forms of active learning was better.

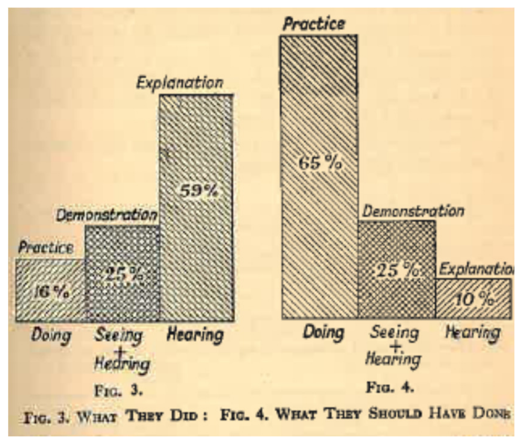


***Figure 4 Classroom time (Mills, 1953)***

3. ***Two ways of learning:*** Active and passive where active learning was more effective than passive learning in specific courses (Ebert-May, et al., 1997), namely, active learning using the methods in the higher levels in Figure 5 are more effective than the methods in the lower levels. Figure 5 contains the original activities in Dale's Cone and the Learning Pyramid, drawn as a horizontal Pareto chart and identifies the active and passive learning activities.
4. ***Deep and shallow learning.*** Deep learning was better (Biggs, 1999).
5. ***Different learning styles:*** ways of expressing and evaluating learning styles including the VARK (Visual, Aural/Auditory, Read/Write, and Kinesthetic) (Fleming and Mills, 1992), the Grasha-Reichmann model (Grasha, 1996) pages 127 and 128).
6. ***Three types of propositional knowledge:*** which provide a useful content-free classification (Woolfolk, 1998; Schunk, 1996) page 166), declarative, procedural and conditional[15] discussed in Section 5.7.

[15] Other ways of classifying knowledge were found, noted and not deemed to be useful in this context.

7. ***Critical thinking.*** There were different definitions of, and ways of measuring, critical thinking, e.g. (Gordon G. et al., 1974; Gharajedaghi, 1999; Wolcott and Gray, 2003).

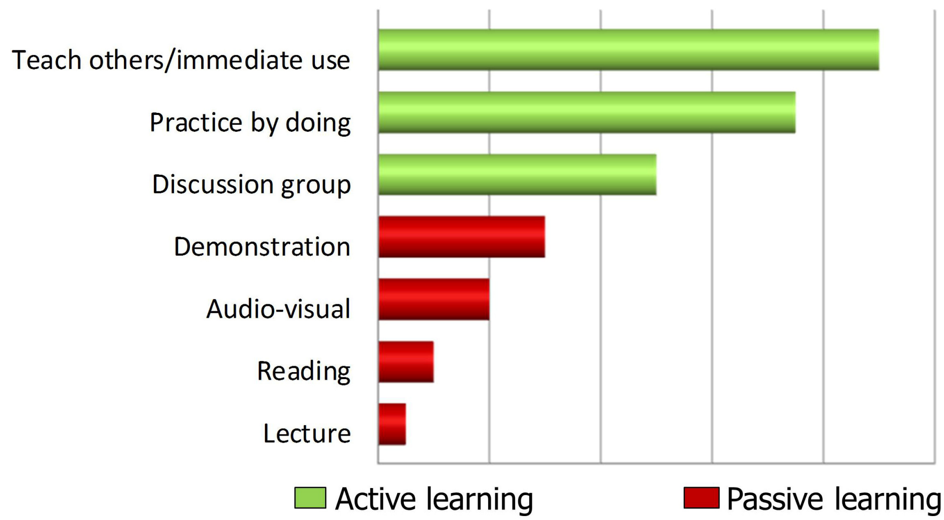


***Figure 5. Claimed effectiveness of different learning techniques***

### 4.2 The process for crafting a degree or class

There seem to be at least three processes for crafting a degree or a course in systems engineering. These are:

1. Benchmarking what other institutions are teaching and copying them so as to position the course or degree on top of the normal distribution curve.
2. Benchmark other universities and bundle common courses with whatever the faculty can teach as a degree program in systems engineering (Kasser and Arnold, 2016).
3. Finding out what needs to be taught and then crafting the course to teach it; the traditional systems engineering model of creating a system to meet a need. This process, shown in Figure 6, combines a number of activities and is iterative (Kasser, et al., 2004). This was the process adopted in developing the balanced classroom.

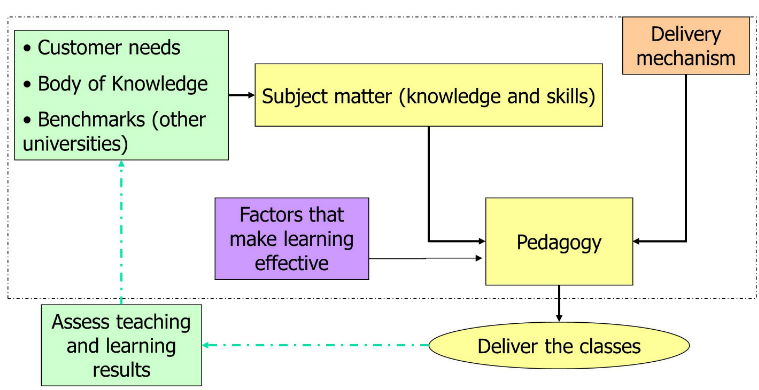


***Figure 6 Process for crafting a degree/course***

### 4.3 Curriculum objectives

The students in the postgraduate courses comprise a mixture of fulltime and part time students. Most of the part time students are funded by their employers. some of the classes are open to the public as in the degree courses and some are bespoke to specific clients and may nor may not lead to academic qualifications. Client organisations are invariably interested in their staff acquiring valuable skills that will translate into enhanced workplace performance in the short term as well as in the long term. Biggs states that, traditionally, teaching for the professions has involved primarily declarative knowledge that deals with labelling, differentiating, elaborating and justifying with the professional procedural knowledge taught separately through experience in practice (Biggs, 1999). It is not surprising then, that postgraduate students and client organisations that are looking for professional knowledge that deals with executing, applying, and making priorities, find traditional university offerings inadequate. Biggs goes on to state that what is really needed is for educational programs to impart functional knowledge that involves declarative knowledge (the academic knowledge base) together with procedural knowledge (the skills) and conditional knowledge (knowing the circumstances for using them). Thus, curriculum and assessment design need to take this into account. An important point is that there is no tension whatsoever between good educational practice and the educational outcome desired by the students and the client organisation from which they come[16].

Biggs uses a four-level framework to categorise the level of understanding achieved of the subject matter:

1. ***Unistructural:*** characterised by a knowledge of terminology and a focussing on one conceptual issue within a complex case; it is evidenced by the ability to recall facts and the ability to do simple procedures.
2. ***Multistructural:*** characterised by the ability to enumerate, describe, combine, and do algorithms. Understanding at this level appears as a disorganised collection of items; the ability to show great detail but the concepts are used inappropriately.
3. ***Relational:*** characterised by the ability to compare and contrast; explain causes; analyse; relate and apply. Understanding at this level is demonstrated by the correct use of concepts to integrate a collection of data and the ability to apply concepts to a familiar problem.
4. ***Extended abstract:*** characterised by the ability to theorise, generalise, hypothesise and reflect. Understanding at this level is demonstrated by the ability to use principles to tackle unseen problems and through questioning and going beyond existing principles.

At the level of an advanced master's degree, the aim is to impart a deep level of understanding of the subject matter, the ability to apply it correctly in the appropriate context, and to draw new insights in the process. Thus, the curriculum needs to be designed to achieve at least the relational level of understanding. It should be noted that undergraduate programs often fail to reach this level and all too often assess the ability of the student to regurgitate lecture notes and text books. Assessment design for the higher levels of understanding needs to look for evidence of the abilities listed and these are unlikely to be displayed in exams. Assessment is usually through substantial assignments that demonstrate deep understanding of the subject matter. It is not unusual for lecturers to comment on early drafts of these assignments to ensure that the work is appropriately focussed and the learning objectives are being demonstrated.

In order to ensure that the students understand the expectations of the program, and of each course within it, it is important to explain how the learning outcomes of an advanced master's degree, in particular one that is sponsored by their employer, are likely to differ from those of their undergraduate programs.

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[16] Students tend to downgrade lecturers teaching conditional knowledge until the reason for doing so is explained. See Section 5.7.

### 4.4 Student attitude

In many government departments and private firms it is customary to assist staff who wish to pursue part-time degrees. This support encourages the staff member to put in a solid effort but should the student fail to complete the program, the consequences are usually minor. In this environment students consider their studies to be something they are privileged to undertake and invariably display a very positive attitude to the programs and the student's focus is on achieving an enjoyable and valuable learning experience.

In contrast, when an organisation selects individuals to attend one of their sponsored programs, it places much greater pressure on the students to do well and there is a noticeable increase in concern from the students about the assessment and how best to achieve a high grade. In addition, in bespoke programs, there is a greater probability that at least a few individuals would prefer not to be involved. These factors contribute to a somewhat less positive attitude amongst the student cohorts in these programs and show up in the post class student evaluations.

It is also noticeable that student cohorts in bespoke programs are noticeably more discerning than public cohorts and expect very high-quality materials and good administrative service from the university. These issues once again reinforce the need to adhere to good educational and administrative practices. It has also been found helpful to invite senior management from the client organisation to address the students during the bespoke program to state the organisation's expectations of the students and to provide personal endorsement of the quality and relevance of the program to the organisation.

### 4.5 A difference between synchronous and asynchronous lectures

The early recordings were for the online classes at UMUC. A difference between synchronous and asynchronous lectures was quickly noted. In the synchronous classroom the discussion is single threaded as shown in Figure 7. The lecture is interrupted by a question and answer discussion. The discussion is summarized and the lecture continues.

This sequential thread is impossible in the asynchronous classroom because of the time delays. Consequently, the lecture is as before, but once the question is asked, the discussion has to be taken off-line and conducted in an asynchronous manner. This leads to a multi-threaded discussion as shown in Figure 8. The implementation of the multi-threaded discussion is via an asynchronous bulletin board, one example of which is shown in Figure 9[17].

[17] Today's classes might use a social media website such as a private Facebook group.

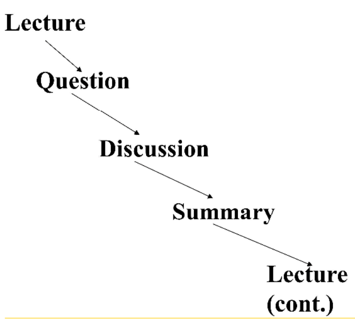


*Figure 7 Synchronous thread*

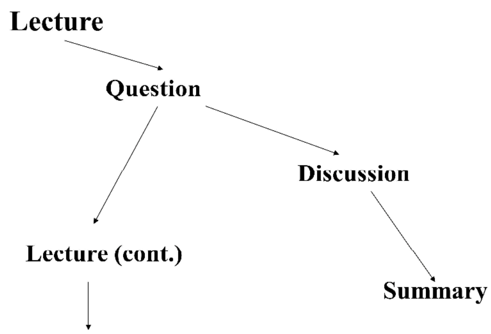


*Figure 8 Asynchronous thread*

## 4.6 Different delivery modes and class formats

As part of my teaching duties, I taught the same class using different delivery modes in different formats both at UMUC and the University of South Australia (UniSA). I was able to use data from these classes to determine if delivery mode had an effect on the learning outcomes as measured by student grades. The delivery modes were:

- ***Semester Mode:*** in which the class is offered for 14 consecutive weeks. In the face-to-face version, the class meets once a week for a session lasting three hours or so at the same day and time in the same location. In the online version, the session lasts for the whole week. The final assignment is due on the last day of class.
- ***Block mode:*** in which the class meets for four or five consecutive a week in a face-to-face environment. The sessions are delivered over the course of the week, and the students have up to 90 days to turn in the final assignment. Post class communications between the students and the instructors take place in several modes including emails, List servers, telephone and even a face-to-face meeting.

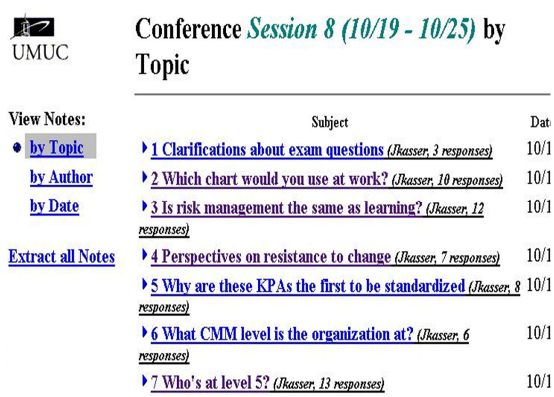


*Figure 9 Asynchronous discusssion forum*

The class formats were:

- The traditional synchronous face-to-face classroom.
- The asynchronous online classroom.

*Table 1 Final Grades for MSWE 648*

| Class | Delivery Mode | Students | Mean | Std Dev |
|---|---|---|---|---|
| 9802 | Face to face Semester | 20 | 86.84 | 6.26 |
| 9909 | WebTycho Semester | 17 | 76.70 | 7.65 |
| 0002 | WebTycho Semester | 17 | 84.71 | 5.83 |
| 0006-0 | WebTycho Semester | 25 | 85.93 | 5.08 |
| 0006-1 | WebTycho Semester | 24 | 83.30 | 8.38 |

- A web-assisted hybrid class.

### *4.6.1 Does delivery mode make a difference?*

Delivery mode is a factor identified in the process for crafting a course shown in Figure 6. I have taught several classes in three different subjects in two different institutions with two different student postgraduate populations. it seems that delivery environment and mode do not seem to affect learning outcomes as measured by final grades as discussed herein.

#### *4.6.1.1 MSWE648 Software Maintenance*

I taught a class on software maintenance (MSWE 648) at UMUC between 1998 and 2000 in the spring (02), summer (06) and fall (09) semesters. The first iteration of the class was in the fall semester of 1998 (9809). The class content was converted to online asynchronous delivery with a slight change of content for each of the following year iterations. However, the assignments remained the same and were assessed by the same instructor. In the summer (06) of 2000, two simultaneous iterations of the class were delivered in distance mode using UMUC's web-based distance learning environment (WebTycho)[18]. The summer necessitated a compressed delivery schedule in which two sessions ran in a week, unlike the 'normal' semester mode of one session a week. The final grades are shown in Table 1 and I did not grade on a curve. Apart from a blip in 9909, when the delivery was converted to online asynchronous Semester format, there seems to be no significant difference in the outcomes.

#### *4.6.1.2 Software Engineering Project Management (MSWE617)*

I also taught Software Engineering Project Management (MSWE617) in two iterations. The first iteration was an face-to-face semester class in 9902, and a web-assisted hybrid in the following year (0002) (Kasser, 2001) discussed in Section 4.10. The web-assisted class was configured with asynchronous WebTycho lectures to a face-to-face class with a face-to-face teaching assistant[19]. Each WebTycho lecture was followed by a synchronous audio link. One group of students worked in a WebTycho environment, the remainder in a face-to-face environment. The grades shown in Table 2 (again not graded on a curve) seem to indicate no significant difference in outcomes. Although only two classes were offered, the results are consistent with those of MSWE 648.

#### *4.6.1.3 Systems Engineering for Complex Problem Solving (SECPS)*

I taught Systems Engineering for Complex Problem Solving (SECPS) in 2003 and 2004 as a bespoke corpo-

*Table 2 Final Grades for MSWE 617*

| Class | Delivery | Students | Mean | Std Dev |
|---|---|---|---|---|
| 9902 | face-to-face Semester | 20 | 89.59 | 2.83 |
| 0002 | Web-assisted Semester | 30 | 88.38 | 3.44 |

[18] The normal WebTycho class size was a maximum of 25 students. Since more students needed the class to graduate. I offered to allow them to participate. A colleague pointed out that if I ran the class in two sections instead of one large class, it would count as double workload and fulfill my teaching requirements .

[19] This can be considered as a flipped classroom by remote control in 2000.

rate class to the Australian Defence Science and Technology Organisation (DSTO) by UniSA. I taught the course in two delivery modes (Block and Semester), and two environments (face-to-face and a non-real-time or asynchronous environment. The course ran four times: there were two Block face-to-face deliveries and one each of Semester mode face-to-face and an asynchronous online environment. Each offering of the class had:

*Table 3 Summary of SECPS Grades*

| Year | Delivery | Students | Mean | Std. Dev |
|---|---|---|---|---|
| 2003 | Block | 35 | 73.28 | 16.38 |
| 2004 | Asynchronous Semester | 14 | 73.71 | 6.3 |
| 2004 | Block | 17 | 76.29 | 5.5 |
| 2004 | Face to face Semester | 49 | 73.37 | 8.4 |

1. The same content – the class had been created for the DSTO just before it was offered for the first time in 2003 so there was little need for an upgrade[20].
2. The same assignment.
3. The same person marking the assignments.
4. The same class format (learning objects).

Table 3 shows the year, delivery environment and mode, numbers of students, the mean final grade (based on a maximum of 100%) (again not graded on a curve) and the Standard Deviation. Using 'final grades' as a measurement it can be seen that there was no significant difference in outcomes between the delivery environments and modes although the Standard Deviation was much wider in the first iteration.

### 4.7 The different technology for recording the lectures

Recording a lecture is simpler than it sounds[21]. Several readily available low cost software packages for PC and smart phones provide that capability. The approach for recording a lecture is the same as that used for making it in the classroom. The instructor goes through the presentation and records what would have been said in the classroom. Unlike in the classroom, the instructor can then review and edit the lecture before the students get to experience it.

The literature review was unable to locate any requirements for the need to see the lecturer during the lecture. There were no answers to questions such as 'was it really necessary to see the instructor or were PowerPoint slides and a picture good enough'? Recognising the similarity between a classroom and a conference presentation, experiments showed that when the lights are down in the conference room, the delegates focus on the presentation and there is little non-verbal communication from the presenter. If the presenter chooses to take questions at the end of the talk, there is no difference between her delivering the presentation synchronously or asynchronously. There thus seems to be no requirement to see the presenter during the presentation, just the presentation graphics.

Student's comments on the difference between the recorded and live presentations were mainly that, "*they couldn't interrupt the recorded presentation with a question*". This was the same response to the same question posed to the audience in the first demonstration/experiment at the INCOSE symposium in Vancouver in 1998 (Kasser and Weiskopf, 1998) when I surprised the session attendees with a pre-recorded presentation. When the pre-recorded presen-

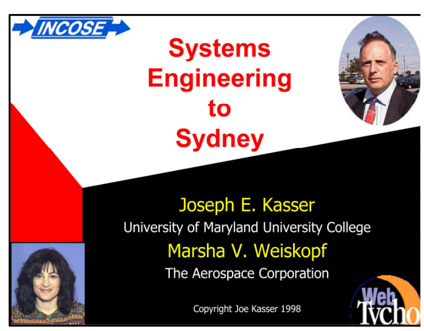


*Figure 10 Title slide from first INCOSE pre-recorded presentation*

[20] The class did undergo an upgrade in early 2005.
[21] Pun intended.

*Table 4 Pre-recorded lecture times (minutes)*

| | CSMN648 | SysEng412 | | SDM5004 | | | | MT5014 |
|---|---|---|---|---|---|---|---|---|
| **Session** | **1998** | **2010** | **2011F** | **2013** | **2011** | **2012** | **2013** | **2014** |
| 1 | 55 | N/A | 19 | N/A | N/A | N/A | N/A | N/A |
| 2 | 47 | N/A | 39 | 35.5 | 46 | 38 | 38 | 30 |
| 3 | 22.5 | 25.5 | 34 | 9 | 35 | 37 | 42 | 41 |
| 4 | 51.5 | 6 | 7 | 28 | 6 | 7 | 12 | 10 |
| 5 | 36.5 | 34 | 37 | 24 | 41 | 35 | 34 | 33 |
| 6 | 38 | 11.5 | 20.5 | 20 | 15 | 20 | 22 | 21 |
| 7 | N/A | 20 | 31 | 46 | 28 | 30 | 30 | 25 |
| 8 | 28 | N/A | 7 | 49 | N/A | 3 | 5 | 5 |
| 9 | 50.5 | 35.5 | 74 | 32 | 39.5 | 79 | 60 | 78 |
| 10 | 61.5 | 20 | 25 | 43 | 23 | 24 | 24 | 24 |
| 11 | 30.5 | 52 | 51 | 59 | 39 | 51 | 51 | 50 |
| 12 | 34 | 35 | 27 | 22 | 36 | 25 | 25 | 25 |
| 13 | 22 | 20.5 | 19 | N/A | 20 | 19 | 19 | 15 |
| 14 | N/A | 6 | 9 | N/A | 6 | 9 | 9 | 9 |
| 15 | N/A | 20 | 24.5 | N/A | 28 | 24 | 26 | 25 |

tation began (see Figure 10) the presenter at the podium raised a soft drink can to his lips and drank from it. When a few of the audience noticed that something was not correct, I stepped out of the room for a moment. The first 1998 asynchronous online classroom pre-recorded asynchronous lecture[22]:

- Used PowerPoint for the knowledge video.
- Comprised individual audio (wav) files for each slide which allowed changes to be made to parts of the lecture without having to re-record the entire lecture.
- Incorporated a picture of instructor on each slide.
- Used Real media (rm) format.
- Lasted 55 minutes, see Table 4.
- Only needed 3.3 Mbytes of storage space.

By 2010, the pre-recorded asynchronous lectures:

- Still used PowerPoint for the knowledge video.
- Used a single MP3 file for the lecture audio.
- Still incorporated a picture of instructor on each slide.
- Needed up to 10 Mbytes for the audio file alone.

In 2015, the pre-recorded asynchronous lectures:

- Used a number of MP4 video files for the video and audio, each 10 to 20 minutes in duration.
- Showed the talking head of the instructor as well as the PowerPoint slides.
- Needed 49GB of storage for one MP4 file.
- Were (some of the lectures) uploaded to YouTube[23].

It seems that 17 years of advances in the state of the art have increased the bandwidth and storage needs but have not added much to the basic lectures. The use of technology is vendor-driven based on what is available, rather than being based on requirements. This is where sys-

[22] The online flipped classroom in 1998.
[23] E.g., those on https://www.youtube.com/channel/UCVBNs9VpnUp6QfytbqzJ96g.

tems engineering can help the domain. Research into the nature of the requirements is needed.

### 4.8 The effect of the difference in teaching styles

There are many problems related to the matching between learning and teaching (Dunn and Dunn, 1979). Among others, the following questions should be answered[24].

1. What are the problems in matching teaching and learning styles?
2. How to design a matching teaching & learning system?
3. Should the matching be done before or after students select a course?
4. What should be the speed of the match, gradual or sudden?

Research and various types of analysis and modelling/simulation tools may have to be employed. If the questions cannot be completely answered the elements of the solution they influence must be monitored. See comment in Section 11 on the validity of learning styles.

#### *4.8.1 Experimenting with learning styles*

In 2009, it seemed plausible that engineering students might prefer different learning styles depending on the content and the kind of assessment expectations which are placed upon them with respect to the abilities that they will be able to demonstrate as a result of the their study (Valerdi, et al., 2009). A postgraduate class on systems engineering at NUS in early 2009 which employed three instructors (Prof A (this author), Prof B and Prof C), one after the other, teaching different topics at different levels of abstraction using different teaching styles provided some useful data (Zhao, et al., 2009).

Student perceptions of the amount they learnt from each instructor and the differences between the instructors, the types of knowledge and the topics taught were examined and analysed to determine if the results of the analysis could provide evaluation criteria as described herein[25]. The variables/parameters in the course included:

- Three types of propositional knowledge discussed in Section 5.7.
- Level of abstraction of the course content associated with the topics taught.
- Instructor teaching styles.
- Topics – each instructor provided a different part of the knowledge component[26].
- Student learning styles.

***Prof A*** provided knowledge using lectures, readings and problem-based active learning. Prof A's teaching style emphasizes conditional knowledge, rather than declarative and procedural knowledge. Prof A's style affects the students in three ways. It:

1. Improves the thinking skills of the students. Prof A provides the outlines and abstracts or overviews of knowledge, and asks open-end questions expecting the students to find the answers and explanations by themselves or in groups. Prof A watches student teams at work and gently nudges them along the path of learning rather than leading the way.

[24] These questions are broad and may require substantial analysis to determine the pertinent parts of the findings of research performed in generating the answers to the questions.

[25] But should students be the only source? Is it reasonable to judge relative merits of courses and instructors on the basis of student perceptions? Are students able to judge how much they have learned (and understood?), and are they able to separate their judgement from their emotions? Is this situation is akin to design departments making decisions on what they think the customer would want without actually asking the customer. Is it also similar to a group only using items they have invented or developed in-house or have direct experience?

[26] Once again the correctness of the knowledge was assumed.

2. Builds team-working spirit, the different group exercises following the introductory lecture are designed for 'learning by doing' in every class.
3. Enriches their experience in receiving the knowledge. Prof A uses multi-media (audio, video and reading materials) as additional knowledge sources for students. Examples included:

   - Using a virtual guest speaker. A 30 minute video by Prof Derek Hitchins on systems engineering was downloaded from his web site (Hitchins, 2009) and played to the students; an asynchronous lecture in the classroom. After the video had ended Prof Hitchins was contacted via Skype[27] and Prof A facilitated a short question-answer and discussion session.
   - Having to be at an overseas International Workshop, instead of missing an evening, the short lecture was recorded and played to the students by a colleague in the classroom; an asynchronous lecture in the classroom. Prof A then checked in to the class using Skype[28] and by the judicious position of the camera on the laptop in the classroom by the colleague was able to view the students working on their class exercise, view their presentations and make constructive comments.
   - Setting a pre-class exercise in which the students were required to download Tiger Pro, an educational requirements tool containing some artificial intelligence that can tell the students if the requirements they write are bad from the testing perspective (Kasser, 2007c). The students downloaded the tool, did the exercise individually before class and submitted an individual presentation on what they had done. Prof A subsequently compiled a summary presentation containing the student-written requirements (anonymously) which showed how and why student written requirements were good and bad.
   - Using the video "Pentagon Wars" (Benjamin, 1998) as a case study. The students were given a set of questions before class, watched the video in class and then answered the questions post-class in their teams. While the students did not seem to realize it, Prof A noted that lessons the students learnt from the video were indeed insightful and informed the student accordingly.

***Prof B*** provides the students with the traditional and familiar lecture using PowerPoint presentation graphics. Prof B teaches the declarative knowledge and demonstrates procedural knowledge in the daily examples within the lecture. All the key information (e.g. concepts, methodology, examples, etc.) are written clearly. Prof B even enunciates 'word by word' the content of the slides. This traditional method has been widely accepted by the students and makes most of them feel comfortable.

***Prof C*** teaches procedural knowledge in class. Prof C delivers knowledge using a combination of the traditional lecture followed by immediate group work. Prof C gets involved in the group work and personally interacts with the students and the groups as a consultant and facilitator. At the end of the exercises depending on the available time, the groups make presentations and share learning.

[27] By prior arrangement.
[28] At 0330 his local time!

***Table 5 Coursework content assessment***

| | Coursework Topics | Level of Abstraction |
|---|---|---|
| **Prof A** | Critical thinking<br>Problem solving<br>Context of system engineering<br>System design life cycle<br>Requirements engineering | High |
| **Prof B** | Risk Management<br>System Real Options | Low |
| **Prof C** | Business Process Reengineering (BPR) concepts<br>Process mapping and analysis<br>Process validation<br>BPR practice | Medium |

***Table 6 Grasha-Riechmann Instructor Self-Assessment Results***

| | Prof A | | Prof B | Prof C | |
|---|---|---|---|---|---|
| **Expert** | 3.5 | Moderate | No data | 4.375 | High |
| **Formal authority** | 4.25 | High | No data | 3.625 | High |
| **Personal model** | 4.25 | High | No data | 3.627 | High |
| **Facilitator** | 4.25 | High | No data | 3.75 | Moderate |
| **Delegator** | 3.87 | High | No data | 3.5 | High |

### *4.8.2 Topics and level of abstraction of course content*

The topics and degree of abstraction of the course content were different as shown in Table 5.

The teaching styles and type of content was different for each instructor. The Learning Pyramid values for the degree of retention of information of the student after two weeks for each of the teaching methods (Lowery, 2002) and the approximate percentage of time allocated by the three instructors to each of the teaching methods is shown in Table 7. Two of the three instructors performed a self-assessment of their teaching styles using an online Grasha-Riechmann (Grasha, 1996) pages 127 and 128) test[29] in May 2009. The results are shown in Table 6[30].

There were 30 full-time and part-time students in the class and using a tailored version of grounded theory (Glaser, 1992), eight students were interviewed about the class and their learning styles using face-to-face and telephone discussions. Each interview lasted about 30 minutes. The student responses were grouped into three types according to the three types of personality (Myers and Myers, 1980).

- ***Type 1:*** these students are introvert thinkers. They:
  - Prefer a quiet environment for learning and listening rather than talking and interacting in class.
  - Make decisions and work directly with data, rather than with feelings, emotions and personal values.
  - Are objective decision makers, who like to get opinions based on established

[29] Available at http://www.longleaf.net/teachingstyle.html in May 2009.

[30] Further research will have to be done to determine the significance of the differences if the information is deemed pertinent to providing the solution. This is illustrative of a situation in which analysis data is incomplete. In such instances if the solution system may be affected by the incomplete information, then the missing information become 'risks' and shall be managed appropriately. The self-assessment was done because Web site showed up on a search and the test was simple and fast. This situation illustrates that while systems engineers measure and perform analysis it is very easy for analysis-paralysis to set in. For example, questions such as "*did the test provide any useful data?*" and even "*why are we measuring this characteristic*?" should be asked and answered. Analysis shall only be done if pertinent to conceptualising the solution, not because the data is available.

***Table 7 Approximate percentage of time each instructor spent in a teaching method***

| Teaching Method | Learning Pyramid | Prof A | Prof B | Prof C |
|---|---|---|---|---|
| Lecture | 5% | 30% | 50% | 50% |
| Reading | 10% | 15% | -- | -- |
| Audio visual | 20% | 25%[1] | -- | -- |
| Demonstration | 30% | -- | 50% | -- |
| Discussion group | 50% | 30%[2] | -- | 50%[2] |
| Practice by doing | 75% | 30%[2] | -- | -- |
| Teaching others/immediate use | 90% | -- | -- | 50%[2] |

Notes

1. One class session used the movie ‘Pentagon Wars’ (Benjamin, 1998) as the basis for a case study.
2. The activities in the two rows in the column happened simultaneously.

facts, known procedures and linear presentations.

- Tend to have stronger skills in memorizing details rather than in understanding abstract picture.
- Prefer concrete language and working directly with data.
- Tend to reserve judgement until all the data has been processed.

- ***Type 2:*** these students:
  - Are more likely to make decisions based on emotions, personal values or vague intuitions.
  - Value group harmony and feel less comfortable with personal conflicts.
  - Tend to have stronger skills in memorizing details rather than in understanding the whole picture.
- ***Type 3:*** these students:
  - Feel more comfortable interacting with others and like talking aloud in public.
  - Believe data and evidence, but most of the time make immediate decisions and drew premature conclusions based on initial inputs.
  - Feel comfortable with accepting abstract knowledge and get the big picture of things first. They then look inside at the internal components, items such as the connections between seemingly random sets of data, and fill in the details later.

Student comments on the different instructor’s teaching styles, by Type, included:

- ***Type 1:*** I felt puzzled when I attended Prof A’s class. There were too many class activities that made learning experience complex. My team members and I always feel stressful and find it hard to enjoy the class. The content of Prof’s B’s class was also not easy, but I am quite familiar with this traditional teaching method. So it is not a problem for me to grasp the knowledge. Prof C’s class made us feel easy to catch up and the number of activities is neither too much nor too little, which even inspire our interest in learning more after class.
- ***Type 2:*** Prof A’s teaching style was quite new for most of us. We didn’t have enough psychological preparation and needed time to adapt to the teaching method. Though the organization of the teaching style is simple in Prof B’s class, the demonstration and lecture notes have enough detail for us to understand the knowledge. Moreover, the active individual presentation skill kind of balances the boring teaching method. Prof C’s class is fun. I like the immediate practice in class, which make me feel effective learning and inspires my interest.
- ***Type 3:*** Prof A’s lecture is at a higher abstraction level for the topics, which make it hard for most of us to grasp them in the short time. But after the module, I felt I

> learned more and my thinking ability improved in Prof A's session, though it is still hard for me to connect it with our daily experience. We are used to Prof B's way of teaching. Though it is a little boring, I feel it doesn't depress our learning effect. What's more, his active personal presentation skills kind of balance the boring teaching method. Prof C's class makes us feel that it is easy to understand the knowledge through the immediate practice. Moreover, it makes everyone perform actively, because there are more chances to consult with Prof C personally in class during the team project.

In this classroom example, from the random sample[31], the majority of the students are introverts and thinking students, perhaps because of their prior engineering background. But the majority also agreed that classroom interaction and being an extrovert are also good for learning. They hoped they could be more extroverted and sociable in the light of their perceptions of the types of students in the business school. These surveyed students would like to become managers in future, managers who can perform decision making and risk management at the business level, rather than remaining as a person who can only deal with data. As the content of their degree program is positioned between engineering and business, and given their prior major engineering background, their preference for subjective and objective decision making is relatively equal.

In summary, there is a difference in the type of knowledge taught by the instructors. Prof A focuses on delivering conditional knowledge, while Prof B and C focus on declarative and procedural knowledge, which make students feel more comfortable (Kasser, 2009). Some students can't get used to the problem-based learning method in Prof A's class because the highly abstract lecture makes them feel unclear about what they have learned. On the other hand, Prof B and Prof C deliver the typical lecture-based class with concrete information in the slides which helps the student understand the basic concepts. Moreover, Prof A and Prof C both employ some forms of active learning. Besides those methods, Prof A's class also involves more up-front investment in teaching resources and methods, such as identifying and creating readings, videos, etc.

When the results from the use of different teaching and learning styles are summarised as being applied in different types of classrooms as shown in Table 8 the data does not appear to be useful and there is no data upon which to make an objective decision as to which of the conceptual classrooms to select[32]. The selection criteria in this case had been determined using student provided data. But are the students a good source of evaluation criteria? There are other stakeholders – instructors, employers and the academic institution (Kasser, et al., 2008). Students can only evaluate that the way in which they were taught, they cannot evaluate that they were taught what they need to know (at least not immediately after the class ends)[33]. Other evaluation criteria need to be identified.

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[31] It needs to be mentioned that the survey results may be biased and limited. This is because people tend to complain during evaluations and sometimes blame others subjectively rather than cite good points. In addition, students get used to relying on the teacher actually teaching in class, and not having to do it themselves (DIY) or self-learn. Moreover, students are reluctant to change their learning styles. Resistance to change is an important element that has to be taken into account when introducing change into any context.

[32] Had there been domain experts in the systems engineering team the results of the analysis might have been different. This result is meant to illustrate the need to have problem domain expertise and experience during the systems engineering problem solving activities.

[33] And will not pick up or question the implied assumption that the knowledge component is correct and complete.

*Table 8 Summary of evaluation of alternative classrooms*

| Conceptual Classroom<br><br>Criteria | Classroom 1<br>The somewhat modified current lecture-centric classroom. | Classroom 2<br>A classroom using pedagogy based on active learning. | Classroom 3<br>A classroom environment which matches student learning styles to instructor teaching styles. |
|---|---|---|---|
| **Teaching styles** | Does not allow much variation. | Multiple styles but not matched. | Matched to student learning styles. |
| **Types of knowledge** | All | All | All |
| **Topics** | All | All | All |
| **Degree of abstraction of the course content** | Suitable | Suitable | Suitable |
| **Student learning styles** | Does not take student learning styles into account. | Variation in activities seems to allow for different learning styles at different times in the class. | Takes student learning styles into account. |

Looking out of the box by posing the *Generic* perspective question *"What is this problem similar to?"* One relevant answer is a digital radio communications system where the 'ability to apply the knowledge in various situations' is the message, the instructor is the transmitter, the student is the receiver and the amount of received signal represents the learning. Maximising the received signal requires that the transmitter and receiver be on the same frequency, use the same modulation, compatible data rates and the message is transferred in an environment with minimal interference. If this analogy holds then the selected solution should be one which matches instructor teaching styles to student learning styles unless a thorough search of the education literature and the opinions of cognizant personnel in the education domain would confirm that in the last 20 years or so, research has shown that matching teaching and learning styles makes no significant difference in the effectiveness of learning systems engineering. Or should it? Implementing Solution 3 would require answers to the questions posed above.

The accuracy of the *Generic* perspective analogy is critical to the success of the project; in this analogy the message is akin to the 'ability to apply the knowledge in various situations'. This analogy would drive the pedagogy towards producing Type V systems engineers (Section 0). Had the analogy stated the message as just being akin to the 'knowledge', the analogy would tend to drive the pedagogy towards producing Type II systems engineers which seems to be common practice (Kasser, et al., 2009) since much of systems engineering is now taught as declarative and procedural knowledge (Section 5.7) as defined by (Woolfolk, 1998). To be fair, perceptions from the *Generic* perspective identified that this focus on declarative and procedural knowledge is not unique to systems engineering (Microsoft, 2008). For example, Peter Drucker wrote "*Throughout management science--in the literature as well as in the work in progress--the emphasis is on techniques rather than principles, on mechanics rather than decisions, on tools rather than on results, and, above all, on efficiency of the part rather than on performance of the whole*" (Drucker, 1973) page 509)[34].

[34] Today's academic institutions seem to be producing Type II systems engineers and managers (engineer leaders); but they should be producing or at least identifying personnel with Type V characteristics by teaching conditional knowledge.

***Table 9 ILS Learning and teaching styles***

| Learning Style | Teaching Style |
|---|---|
| Sensory, intuitive-perception | Concrete, abstract-content |
| Visual, auditory-input | Visual, verbal-presentation |
| Inductive, deductive-organization | Inductive, deductive-organization |
| Active, reflective-processing | Active, passive-student participation |
| Sequential, global- understanding | Sequential, global-perspective |

#### *4.8.3 Future research*

The majority of students in the sample were introverts. This situation is supported by (McClure, 2004) who when reviewing (Laney, 2002) began the review with "*Are you an introvert? Only a quarter of the general population is, but more than half of engineers are*". So even though learning styles have been discredited, and the difficulty of matching teaching and learning styles has been mentioned, further research into the pedagogy for classes teach ing systems engineering could be based on (1) verifying a hypothesis that systems engineers, as a subset of engineers, tend to be introverts and then (2) creating a classroom teaching and learning system based on the learning styles of introverts as the norm. And finally (3) testing to determine if the class is more effective than a class not using the learning styles of introverts as the norm. The Index of Learning Styles (ILS), (Felder and Soloman, 2008), a model which classifies instructional methods according to how well they match the teaching and learning styles shown in Table 9 would provide a basis for the design of the pedagogy.

### 4.9 The development of the knowledge reading concept

After noting that some students were not reading the required material before the session, research into how to ensure the students did read the material commenced. The knowledge readings (Kasser, 2013b) discussed in Section 6.4 overcame that limitation.

### 4.10 The hybrid class: Software Engineering Project Management (MSWE617)

The hybrid class was a challenging class which contained one traditional face-to-face (Face-to-face) synchronous section in Maryland combined with one asynchronous online section with an instructor in Adelaide, Australia. This class used the findings from applied research which began when University of Maryland University College (UMUC) inaugurated its Master of Software Engineering (MSWE) degree in 1999. However, from the beginning, the success of the degree was contingent on having all subjects available via web-based distance learning within two years from the inauguration. This factor was taken into account when creating the degree. The content of each class were configured such that the students[35] would be able to perform any "laboratory" work on their own personal computers. The only risk to the web-based degree was the final project class (MSWE 617) which was designed to be the capstone class in the program. MSWE617 may be considered as a comprehensive examination covering the application of the tools, skills and techniques the students have acquired in the course of their studies. This class provided experience in applying software-engineering techniques by giving the students an opportunity to produce software working in teams under the schedule constraints commonly experienced in industry. The students had to produce the appropriate documentation for the SDP as well as the working software, although the grading was designed so that the students could pass the class if the scope of the software development effort was such that the students could not complete the software by the end of the semester.

[35] These students were employed in the workforce and earned their degree by studying part time, mostly in the evenings. Their employment positions ranged from programmers to project managers. Some also had up to 20 years of experience in their respective fields.

The class was a collaborative learning environment. The instructor was not present in a teaching role, but was only supposed to emulate the vagueness shown by typical customers in describing requirements and serves as a guide and mentor. The students were expected to have acquired the knowledge of what to do and how to do it from the prerequisite classes. It was up to the students to form their own teams (organization) and schedule their work to meet the deadlines imposed by the contract (syllabus).

The distance mode web-based class would be taking place in UMUC's web based distance learning environment (WebTycho). This was a constraint imposed by the institution.

### *4.10.1 The Operational perspective*

Perceptions from the *Operational* perspective included the class was designed so that the class would only meet at the following formal milestone reviews:

- Kick off in the first class in the semester.
- Operations Concept Review (OCR).
- Systems Requirements Review (SRR).
- Preliminary Design Review (PDR).
- Critical Design Review (CDR).
- Delivery Readiness Review (DRR) and last class in semester.

However, the students were free to meet in between times, as and when, they decided to do so.

### *4.10.2 The Functional perspective*

Perceptions from the *Functional* perspective included:

- Audio lectures by the instructor using PowerPoint graphics. This wasn't a problem. The technology had already been used in other WebTycho based classes in the program (Kasser and Kerby, 1999).
- Public (class-wide) and private communications between the instructor and the students. This wasn't a problem. The technology had been used in other WebTycho based subjects in the program. The rule of thumb for these communications had been as follows. If it was:
    - ***Public:*** a question that in the classroom would be asked aloud in front of other students in the class who would benefit by the reply, post it in the appropriate thread or on the Listserver.
    - ***Personal:*** as in asides after class, or during the break in the classroom, use E-mail, fax, voicemail or synchronous communications (telephone or Voice over the Internet (VOIP)).
- Students presenting PowerPoint presentations with recorded audio. This wasn't a problem. The technology had been used in other WebTycho based subjects in the program.
- Transfer of documents between the instructor and students. This wasn't a problem. The capability was built into WebTycho.
- Students sharing documents. This wasn't a problem. This capability was built into WebTycho.
- An effective web-based collaborative learning environment for the students. This was the highest risk. Students were already collaborating on simpler projects in WebTycho to produce single documents with what appeared to be the usual mixed results of students working in teams. The WebTycho version of this class would require that the students produce a suite of documents as well as a working software product.

Thus, the reuse of techniques from other WebTycho classes provided most of the functionality needed for the WebTycho version of MSWE 617. The only risk remaining was to determine if the students could complete a software development project in the WebTycho environment.

#### *4.10.3 The Continuum perspective*

Perceptions from the *Continuum* perspective include postgraduate seminar classes are spread out along the spectrum of synchronicity shown in Figure 3. The difference between teaching in the synchronous (face-to-face) style of the traditional classroom and the asynchronous web classroom may be as great at the difference between the theatre and television in the entertainment industry (*Generic* perspective). This means that techniques that work in the synchronous classroom may not work, or may have to be modified to work, in the asynchronous classroom. Consider some of the differences:

- ***Dialogue:*** unlike the face-to-face classroom, the asynchronous classroom has to use non-visual and non-verbal dialogue. Mechanisms such as the requirement for regular task completion, evaluation of frequency and depth of interaction (i.e. making it 'count') and hooks such as regular postings requiring student responses can be used effectively in classes where dialogue constitutes a significant learning resource.
- ***Attendance:*** unlike the face-to-face classroom with its fixed meeting times, the asynchronous classroom is available for longer periods of time in which both the student and instructor appear at sporadic or periodic time intervals. This requires specific time management skills.
- ***Lecturing:*** there is a difference as discussed in Section 4.5. Unlike the face-to-face classroom where lectures are interspersed with question-and-answer discussions as shown in Figure 7, the asynchronous classroom is multi-threaded not single-threaded as shown in Figure 8 since the instructor cannot wait for a few days before continuing the lecture. Asynchronous pauses can, however, be advantageous to the learner who (depending on learning style and language proficiency) can benefit from the time available for reflection before responding to or asking questions.
- ***Technical limitations:*** there are things that can be done in the face-to-face classroom that as of the moment cannot be done in the on-line classroom. Designing the optimal asynchronous classroom requires going beyond systems thinking and perceiving the capabilities and limitations of the entire communications link between the students from the perspectives perimeter.
- ***Team building:*** unlike the face-to-face classroom in which a team can begin to form in a few minutes as the prospective team members sit and talk, forming successful teams in the asynchronous on-line class requires a completely different approach. However, once developed, this approach can be retrofitted to the synchronous classroom to facilitate team building in that environment.

#### *4.10.4 The Scientific perspective or the solution system design*

The class (system) was designed as two subsystems, the instructor and the classroom. The classroom contained further subsystems, the student teams and the teaching assistant. Location and technology was interchangeable. The problem-solving approach taken was an evolutionary transition approach building on integrating working concepts following the evolutionary transition from the synchronous to the asynchronous classroom methodology shown in Figure 11.

### *4.10.5 The evolution from asynchronous to synchronous lecture formats*

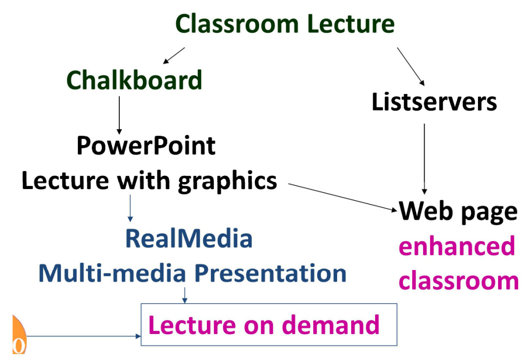


*Figure 11 The evolutionary online transition process*

The evolutionary process was designed so that each step along the way provided a meaningful capability in itself as well as a baseline, so the conversion could take place at a comfortable pace. Consider the evolution from asynchronous to synchronous lecture formats. Moreover, since the development of the online version of MSWE617 was taking place in parallel to developing and delivering other asynchronous classes, each step was tested in an asynchronous classroom environment.

The starting point was the face-to-face class where in many instructors lecture from notes, and write and draw on the whiteboard in real time to enhance the spoken lecture. The first step in the transition is to put what would have been written on the whiteboard into presentation graphics that can be handed out to the students before the lecture begins. The time that the students spent on drawing and copying can then be spent on discussion and constructive learning.

At the same time, there are many instances when there is not enough time in the classroom to cover all the topics, or the discussion gets involved and has to be prematurely terminated because the three hours are up. Listserver technology[36] was used to enhance the discussions in 1999 by continuing them on-line in an asynchronous manner via e-mail. We could even use the Listserver to introduce new topics that were not covered in the classroom. Another use for the Listserver was to allow students who were shy about speaking in the synchronous face-to-face class, to post comments via the anonymity of the written communications medium. The presentation graphics for each lecture were also posted on the class web site. This saved sending files via e-mail and their possible rejection by e-mail host software as being too large for the system. It also provided an archive for students who lost their copy and to potential students the following semester who wanted to know about the class before enrolling.

The next major step of the transition process was to record the sound. This is simpler than it sounds[37] as discussed in Section 4.7. Several readily available low cost software packages provide that capability[38]. The approach for recording a lecture is the same approach as that used for making it in the classroom. You go through the presentation and record what you would have said in the classroom. Unlike in the classroom, you can then review and edit it before the students get to experience it. The presentation is then placed on the web site for downloading, truly a lecture-on-demand.

### *4.10.6 The original plan*

The plan was that the first and second iterations of MSWE617 would be traditional face-to-face sections in the classroom; and the WebTycho class be designed using the lessons learned in those iterations. However, by the time the second iteration ran, several students in the programme had moved out of the local area and needed the class to graduate. Had the original plan been followed, those students would have had to delay their graduation by at least year

[36] Today's technology offers several options to transfer text messages between students and instructors.
[37] Pun intended.
[38] These days the recording functionality is built into cell phones and hand-held MP3 music players.

while waiting for the WebTycho class to run. To avoid this situation, the plan was changed to allow the second iteration to be modified into a hybrid class[39].

A hybrid class proved to be an excellent way to mitigate the risk invoked by a totally WebTycho based class as it provided an opportunity for a side-by-side experiment between the face-to-face student teams and the distance mode student teams. The hybrid class was designed as follows:

- There would be several teams of four to five students, depending on the enrolment. At least one team would be a distance mode team accessing the class purely via WebTycho to cater to the students who had moved out of the area.
- Each milestone review would be presented using a mixture of synchronous and asynchronous techniques. The formal presentations would be done asynchronously, via WebTycho. This approach would allow all the teams to preview the presentations before the reviews.
- The discussions would be face-to-face and via WebTycho. This, and the asynchronous reviews for all teams, would allow the WebTycho teams to feel part of the entire class.
- The face-to-face teams had the choice of meeting face-to-face or using WebTycho and other non-face-to-face techniques.
- The WebTycho teams were prohibited from meeting face-to-face even though some team members would be in the local UMUC service area.

All students enrolling in the class that semester were offered the opportunity to select between the WebTycho and face-to-face sections and were assured that there would be no assessment penalty if the experiment failed. While there were really too few distant students to make up a viable team[40], enough local students chose the WebTycho option to form one WebTycho team.

### *4.10.7 Expect the unexpected!*

After the plan had been finalised the instructor decided to relocate half way around the world. This meant that not only would there be distance-students; there would also be a distance-instructor. While distance-instructors were commonplace in the WebTycho classes, there hadn't been a distance-instructor in a face-to-face class – a major risk to the success of the class.

Drawing on the results of on-going research mitigated the risk. While in the process of converting other subjects in the MSWE programme from face-to-face to WebTycho and employing asynchronous PowerPoint enhanced audio lectures, I had perceived, that from the *Generic* perspective there was very little difference between a classroom and a conference session and had experimented with distance mode conference presentations with the aid of the session chair (Kasser, 2000). Using this perception, it was hypothesized that if the instructor was considered as a distance mode presenter, all that was required was a session chair or teaching assistant to be present in the classroom to facilitate the face-to-face milestone review meetings. So a session chair was appointed in the guise of a teaching assistant acting in the two areas of activity associated with the class. The first area was in the running of the hybrid classroom. The second area was in the continual development of the class to make it function entirely in the WebTycho environment in future. In particular, the teaching assistant had the following duties:

[39] We should have thought of this ahead of time.
[40] Was it worth the effort for those few students? Yes, the students came first.

- Help develop the student project ideas by interviewing potential clients within the University.
- Act as a single customer interface between students and university staff to minimize impact on staff workload while students were developing the software.
- Assist with recording student presentations as necessary.
- Represent the instructor in face-to-face meetings as appropriate.
- Monitor the class with the goal of being able to assume the role of (back-up) instructor in the following iteration.
- Assist in developing and testing techniques for use in WebTycho classes in conjunction with UMUC research grant applications.
- Assist in developing a model for future instructor/teaching assistant roles in the hybrid classroom.

The modified plan for the hybrid class was that the instructor would "lecture" in the asynchronous mode as planned. However, instead of attending the face-to-face meeting in person, he would do it via distance mode, either using VOIP, or the telephone. He would phone in at a prearranged time and talk to the students.

#### *4.10.8 The results*

The results exceeded expectations. After some early equipment problems with the communication links at UMUC, the class was a success. The project products were produced on schedule just as in the prior face-to-face section of the class and there was little difference between the performance of the WebTycho team and the other teams.

The session chair did a great job both as a teaching assistant and as an "IT Technician". We both put in many extra hours to make the class work, some planned, and many not planned. After an initial high volume of e-mail to clarify the situation to all concerned, the volume settled down to a thin trickle and the pressure was off[41].

With respect to the milestone review meetings, the distance instructor's feelings after the first one were that I was not needed; the session chair had everything well in hand. After the second session, I really was not needed. When I telephoned in using VOIP, the main question the students had was deciding when the class would meet next. I stayed on-line at the end of the VOIP link for a while, but was not needed. Since it was a hybrid class, the WebTycho team were asked if they wanted the Milestone reviews to be live on-line (synchronous) using chat room technology. Their response, in the main, was negative. They preferred the asynchronous approach, in which questions and points raised at the face-to-face meeting were posted in WebTycho after the meeting had ended. There became no need for the instructor to "attend" the meetings, and then when the technology failed for a short period of time, my absence didn't seem to make any difference.

The software produced by the students was not just an academic exercise. The software performed useful functionality. The most difficult aspect of creating the class was to size the problem so the software to provide the solution could be created during the course of a single semester. The UMUC administrative and teaching staff were the customers for the standard projects, however students could propose their own programs if they could talk their team into working on it.

One other innovation was produced by the students. The last class session was also a small celebration and the students produced the cake emulation of a computer shown in Fig-

[41] When things go as planned and no issues arise, then nobody realized how much effort was put into preventing those issues from arising in the first place.

ure 12. The innovation however was limited to the students in the classroom since the distance students and distance instructor were unable to partake of the cake.


*Figure 12 MSWE617 celebration cake*

### *4.10.9 Conclusions*

Asynchronous distance mode can be used in the face-to-face classroom in a hybrid style. This opens up opportunities for remote guest speakers and instructors.

The hybrid section of MSWE 617 pushed the envelope, not only in the teaching area, but also in the area of on-line collaborative working in geographically distributed groups. The success of the experiment resulted in a template for a WebTycho only section of MSWE 617, as well as a potential solution to UMUC and other postgraduate institution's universal staffing problem in the area of software engineering.

## 4.11 Integrated Multidisciplinary Engineering for the 21st Century

I developed this course developed at Cranfield University under a grant from the Leverhume Trust in 2007 (Kasser, et al., 2008). Unlike current similar systems engineering courses which focus on the systems engineering process for the knowledge component process, this course:

- Viewed systems engineering from the problem-solving perspective.
- Focused on the three legs of a systems engineer (Kasser, 2007b) which are:
    1) Systems engineering.
    2) The application of systems thinking.
    3) Interpersonal communications.

### *4.11.1 The structure of the course*

The structure of the course was strongly cooperative employing active learning and authentic assessment. The course provided a flavour of systems engineering with a broad overview discussing the context for systems engineering, the competencies needed to perform systems engineering and the states of the system lifecycle employed in systems engineering. The application and assessment of systems thinking in the various states of the project lifecycle was employed in the problem-based learning exercises to enhance the learning experience. The repetition in the exercises improves competence in the appropriate skills needed by the systems engineer.

The sessions were designed so that there would be learning from different sources of knowledge. Each module started with a very short lecture to set the context. During the team exercise, the students divided the readings into parts, with each student reading a part. The primary purpose was acquiring the knowledge in the readings, while the secondary purpose was for the students to each become "experts" in what they read, and then bring that expertise to the team. This emulated the real world of multidisciplinary teams, where they would have to deal with subject matter experts and develop a trust of their level of competency. The design goals for the session components were based on:

- Meeting the knowledge and skills requirements identified from the stakeholder needs,

- Being in accordance with then modern pedagogy which stated that listening and reading were the worst ways to retain information, while doing and teaching were the best, and
- The need for systems engineers to be able to work together in teams.
- The exercises were designed to allow the students to identify their progress and know that they were learning. “Management by Objectives” (Mali, 1972) was used as a guide because it allowed for specific objectives to be set for each exercise, and the presentations following the exercise would demonstrate how well the goals were met (or not). The goals for each exercise were set “*in such a way that they are (1) specific, (2) difficult, but (3) attainable*” (Jain and Triandis, 1990) given that such a combination of goal attributes resulted in maximum motivation of researchers[42].

The hardest part of the course development was the need to reduce the lecturing component, but still impart the knowledge. This was done by a combination of:

- The courseware components.
- Not only allowing time for the students to read the material during the exercise, but making it an essential emulation of the systems engineering workplace.
- Ensuring that the instructor walked around between the teams, monitoring what they were doing, answering the rarely posed question, providing guidance for how to proceed, and making sure the teams met the schedule (completed the exercise within the module).
- Designing the exercises, so that the first exercise was also a teambuilding exercise, the second exercise also set a baseline for student self-evaluation, and the remaining exercises built on each other.

As an immersion course, the course emulated the systems engineering environment in several ways including

- Students learned that projects fail for a number of reasons including poor communications between supplier and customer and poor requirements management.
- Unlike in the typical classroom a complete set of instructions and information could not be found in a single place.

These points were emphasised in the pedagogy as follows:

- The students were informed that information needed to complete the exercises was cumulative[43.]
- The requirements for the post class assignment and the content of the presentation to be made in the last session were given both in writing and verbally, as the class progressed. The students learned about requirements traceability matrices and were advised to use an assignment Requirements Traceability Matrix to ensure that their assignments are complete.

#### *4.11.2 The delivery and the results in the classroom*

The course was first delivered in Cranfield University to eight students commencing their Engineering Doctorate program in November 2007 in Block mode over four consecutive days. The course was also delivered in Block mode over four consecutive days to 50 students at NUS in January and repeated to 13 students in May 2008. The NUS students were mature students in the workplace taking the course for continuing education purposes.

[42] The students are doing research in systems engineering in the manner of (Hall, 1962).
[43] Information for previous modules is to be used in all exercises.

Table 10 Responses from May 2008 Student Evaluation forms

| Statement | Average | Std Dev | Median |
|---|---|---|---|
| The group exercises were excellent | 3.8 | 0.7 | 4 |
| The ratio of lecture to group exercises was just right | 3.1 | 1.0 | 3 |
| The course met my expectations | 3.5 | 1.0 | 4 |
| I would recommend this course to my colleagues | 3.6 | 1.0 | 4 |
| Other courses should use a similar ratio of lecture to exercise | 3.1 | 0.9 | 3 |

In all three delivery instances, the students were initially not prepared for the intense immersion format of the course. They arrived on the first day expecting the usual lecture format. They took a while to get used to the style and format of the course, but by the end of the third day, they became familiar with what was expected of them.

During the delivery of the course in Cranfield University (November 2007) and NUS (January and May 2008), the students in the courses demonstrated a better understanding of systems engineering on the second day of the four-day course, than students at UniSA had shown at the end of traditional five-day courses.

#### *4.11.3 Student comments on the course*

The student course evaluation survey contained 21 statements to which the students responded on a 5-point Likert scale. The responses for five of the statements on the NUS January 2008 course student evaluation forms are shown in Table 10. Responses to the same statements in the Cranfield University and NUS May 2008 course student evaluations were similar. The sample size at Cranfield was too small for meaningful conclusions other than they tend to support the findings at NUS.

The students were asked to

1. Comment on the pedagogy, administration and instructor in the course evaluation forms. While the best thing about the course was selected by a majority to be its hands-on format, the worst thing was its hectic schedule.
2. State the three most important topics they learnt in the course. This was an open ended question. The topics with the most number of selections were the following pure systems thinking templates templates/mnemonics (Kasser, 2013a):
   - OARP – observations, risks, problem template for sorting out the problem in a given situation.
   - FRAT- functions, requirements, answers and tests template for designing an answer to the problem based on a modification of (Mar and Morais, 2002).
   - SPARKS - schedules, products, activities, resources, risks, and the relationships between the previous items mnemonic.

   Presentation skills were the next most important topic.
3. State the least useful topic. Most students responded with a “nil”, “nothing”, a blank or equivalent.

These results were surprising since they completely ignored the traditional applied systems engineering knowledge.

#### *4.11.4 Six-month NUS follow up*

Six months after the course conducted at the NUS in January 2008, a selection of the students who were mostly practising systems engineers were asked to provide feedback on whether the course was effective for them, and how it helped them to apply the knowledge gained from the course to their work. The students were aware of the expectation by their employers to apply the learning from the course to their workplace. They were also aware that the course provided an understanding of how to map the learning to their employers' processes, but admitted that it was challenging to make changes to their work processes and it would take time to do so gradually[44].

#### *4.11.5 Unconventional teaching methods*

The teaching methods employed in the course were radically different from the lecture-based format typically used in local schools and tertiary institutions. With presentation slides and symposium papers as the main course material, the students were not accustomed to the lack of a "core text" book. As the unconventional delivery method of the course was not explicitly made known to the students beforehand, the students felt that they were not "mentally prepared" and thus were unable to fully appreciate and maximise their learning experience from the course.

The value of the course compared to more traditional formats, was yet to be clear to the students. They discovered in hindsight that they could find in readily available textbooks the required information to manage the simulated project work. Thus, even though the reasons for the pedagogy (the learning pyramid, etc.) had been explained in the initial module, they could not fully understand the reasons for the unconventional teaching methods when textbooks seemed sufficient[45].

#### *4.11.6 Experience levels*

Students with inadequate working experience found the concepts insufficiently elaborated during lectures and the pace of group work too fast to "internalise" concepts[46]. On the other hand, students who had many years of working experience and were already applying systems engineering concepts in their daily work, did not feel that they benefited significantly from the course. This was because they were already practising the concepts presented in the course, in one form or another[47].

In the six-month feedback from the students, it was suggested that the immersion course would be effective for intermediate employees with 2-5 years' experience, when they have become familiar with technical tools and are ready to solve large-scale engineering problems.

#### *4.11.7 Intensity of the course schedule*

Another feedback from students was that the course schedule may have been too intense, and they were feeling exhausted after each day of the course[48]. The students acknowledged that the simulated project work was a positive experience, but the stressful schedule may have affected their retention of the learning from the course.

#### *4.11.8 Socio-cultural factors*

The socio-cultural environment is an influential factor on a course consisting of numerous activities requiring interaction and cooperation among students. It had been observed that Singaporeans involved in systems engineering were generally more reserved compared to their western counterparts, and were thus less likely to initiate or spontaneously participate in

[44] This finding is not unique to this situation.

[45] The declarative and procedural knowledge is indeed in the textbooks, but the conditional knowledge is obtained in the exercise and that needs to be conveyed to the students in a better way.

[46] A prerequisite of some systems engineering and project experience was set, but not adhered with in placing students in the class.

[47] This finding was also true in the traditional lecture-centric courses.

[48] A standard problem with the intensive block-mode format.

discussions within unfamiliar groups of people. Indeed, the students had to be prompted to enter a dialogue with the instructor.

#### *4.11.9 Lessons learned*

The lessons learned from the Cranfield and NUS sections include:

- Students may not be asking the necessary questions. In the presentations in session 13, one team at NUS produced a system which was not compliant to instructions (requirements) as a result of a lack of communication[49]. The systems engineering was good, however the project failed.
- Students tend to focus on incremental improvements to prior knowledge. This was evident in the different approaches in the NUS presentations, and even though they were encouraged to copy good techniques used by other teams, most took a while to do so.
- Students can be resistant to instructions. The Cranfield University students were told about OARP but had a tendency not to use it. Consequently, the module was modified to provide an OARP template in the lecture component at NUS, and it was then used by the NUS students appropriately. The Cranfield University students misunderstood one part of the SPARKS mnemonic as demonstrated by their presentations in the final Module. This misunderstanding was corrected in the discussion after the presentations[50], but the misunderstood interpretation remained uncorrected in the student assignments.
- While the sample size was small, it appeared that the Cranfield University students who used the Requirements Traceability Matrix for their assignment, as instructed in Session 7, tended to do better than students who did not use it. In addition, the students were advised that they could discuss the assignment with the instructor for up to three weeks following the class, but none did so[51].
- There are three types of systems engineers based on the ability to deal with vagueness as mentioned above. The format of this course allowed the instructor to observe these characteristics in the students during the exercises. Serendipitous? Perhaps, but the experience in designing the DSTO CEI may have influenced the design of the course, since one of the early purposes of the DSTO CEI was to identify students who were potential PhD candidates while they were studying towards a Master's by coursework degree.
- In any teaming environment, there is always a risk of weak teams. The requirements imposed on the teams for self-selection would usually work, but not in the case of one team in this course.

### 4.12 Missouri University of Science and Technology (MS&T) SysEng412 class

I taught SysEng 412 Complex Engineering Systems Project Management at Missouri University of Science and Technology (MS&T) in the Fall 2010 semester as a distance-learning class from Singapore. The class was designed to optimize the learning experience based on the needs of postgraduate employed students studying in their spare time (Kasser, et al., 2008). The design of this iteration of SysEng 412 included a mixture of lectures, readings and problem-based learning activities using both synchronous and asynchronous activities. When the semester began:

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[49] The students were developing two systems in parallel. The session exercise presentations were on one system. The students were supposed to apply that knowledge to a second different system. Apparently this team failed to do so.

[50] At last the instructor thought he had corrected it.

[51] This is also not unique to this course. Students in traditional courses at UniSA also did not avail themselves of similar opportunities.

- The study materials were loaded into Blackboard for asynchronous downloading prior to the weekly Webex synchronous session.
- The lecture was given synchronously.
- The students worked together synchronously and asynchronously and made a synchronous presentation in the weekly Webex synchronous sessions.

However, a week or so after the semester began an anomaly showed up in the synchronous lectures. The instructor's Webex audio suffered from distortion that made it unintelligible at times according to some but not all students. Upon enquiring about the situation, the support staff acknowledged that this was a recurring problem when the instructor was located outside the USA. The traditional non-systems view might have organised the subsystems as:

- A face-to-face classroom at MS&T equipped with the appropriate synchronous technology for including distant students in the learning process.
- The students in the face-to-face classroom[52].
- A synchronous distance-learning classroom using the Webex platform.
- An asynchronous distance-learning classroom using the Blackboard 9 platform.
- The distance mode students in the USA.
- The instructor in Singapore.
- The email system for asynchronous communications.
- The real-time support staff at MS&T. Note, support was available online during each weekly session and offline in non-real time with a timely response.

On the other hand, the systems perspective partitions the system into two subsystems and an interface system. The subsystems are the:

- Instructor.
- Students.
- Interface subsystem consisting of the classrooms and other facilities.

This approach allowed the interface system to be quickly redesigned to keep the learning experience optimal. Subsequent lectures were pre-recorded as MP3 voice quality bandwidth audio files and uploaded to the Blackboard area for the specific session together with the lecture slides. The students downloaded the lecture audio files together with the lecture slides and listened to the lecture asynchronously prior to the Webex synchronous session. The redesigned lecture faced a delivery domain problem due to the differences between synchronous and asynchronous lectures. The major ones being that:

1. The students could not ask questions in an interactive synchronous manner during a pre-recorded asynchronous lecture. The lecture was delivered in the synchronous classroom by presenting the PowerPoint slides silently, advancing the slides and pausing about two to five seconds on each slide and asking the students to call out when they had a question. When a question was posed, I answered it and sometimes there were also be some comments and additional questions from other students. I was also add a verbal comment to a slide that linked the slide content to something that was presented by the students in an earlier presentation during the session.
2. The need to keep the audio synchronized to the PowerPoint video due to the use of two files since a video MP4 file would have exceeded the system file size limits. This drawback was overcome using domain knowledge in the following manner.
    - The instructor would cue the students to change slides during the pre-recorded

[52] There weren't any in this instance.

lectures using wording such as "and on the next slide". Additionally, every now and again during the talk, the instructor would mention the slide number as a synchronization signal. At the appropriate points in the lecture where the instructor would pause and ask for questions, an 'any questions slide' was inserted into the lecture slides. The questions were posed asynchronously and a comment was added to each question that answers would be provided in the interactive session.

- The asynchronous lecture was reformatted to allow for multiple threads so that later content did not depend on a previous discussion in the same session as discussed in Section 4.5.
- During the interactive synchronous session, the instructor paged through the lecture slides summarizing the lecture, sometimes adding additional information and always stopping at the appropriate places for questions and comments.

The students soon caught on to the idea and the end result was a shortened synchronous session which allowed the students to spend more time on the problem-based learning activities (even more optimal). Indeed the system was flexible enough so that on one occasion when the instructor was travelling to a conference at the exact time the synchronous session was due to take place, the pre-warned students were able to prepare and upload asynchronous presentations to Blackboard and the whole session took place asynchronously (presentations and post presentation dialogue (questions and comments)) in Blackboard.

## 5 Requirements for the balanced classroom

The research and development discussed and summarized in Section 4 developed the requirements for the pedagogy of the class (Kasser, 2007a). This section summarizes the updated requirements and the reasons for the requirements, namely:

1. The pedagogy of the class shall provide industry and government with a pool of skilled personnel for the acquisition and maintenance of the systems that underpin 21st century civilization.
2. The pedagogy of the class shall provide students with the opportunity to exercise the five top aspects of the engineering design process that best equip secondary students to understand, manage, and solve technological problems (Wicklein, et al., 2009).
3. The pedagogy of the class shall use the most effective teaching and learning approach.
4. The pedagogy of the class shall produce Type V systems engineers (Kasser, et al., 2009) and project managers.
5. The pedagogy of the class shall assess the cognitive skills of the students including the degree of critical thinking.
6. The pedagogy of the class shall maximise student attention span.
7. The pedagogy of the class shall teach the three types of propositional knowledge.
8. The pedagogy of the class shall provide the students with the opportunity to exercise the modified Blom Taxonomy higher level skills and competencies.
9. The pedagogy of the class shall include real world scenarios to provide an experience component.

Consider each requirement.

### 5.1 A pool of skilled personnel

Industry and government require a pool of skilled personnel for the acquisition and maintenance of the systems that underpin 21st century civilization (Kasser, 2007b). These personnel:

1. Are competent, skilled and knowledgeable systems engineers and project managers capable of effectively working on various types of complex multi-disciplinary integrated systems in different application domains, in different portions of the system lifecycle, in teams, alone, and with cognizant personnel in application and tool domains.
2. Have a firm foundation based on three legs (Kasser, 2007b):
   - ***Systems engineering:*** knowledge of systems engineering processes, experience in systems engineering processes.
   - ***Ability to identify and solve correct problems:*** systems thinking, critical thinking and problem-solving.
   - ***Interpersonal skills:*** including communications and personal relationships.
3. Need to understand the principles of systems engineering and be able to explain the principles to their juniors.

### 5.2 The five top aspects of the engineering design process

The five top aspects of the engineering design process that best equip secondary students to understand, manage, and solve technological problems (Wicklein, et al., 2009) were:

1. Understanding that there may be multiple solutions to a problem/requirement.
2. Effective oral communications.
3. Ability to communicate graphically and pictorially.
4. Ability to handle open-ended/ill-defined problems.
5. Ability to perform systems thinking.

### 5.3 The most effective teaching and learning approach

Findings from the first research question "*What factors make learning effective?*" summarized in Section 4.1 determined that the class should use exercises that emulate the workplace; a technique now known as authentic learning and assessment.

### 5.4 Produce Type V systems engineers and project managers

Perceptions of systems engineering from the *Quantitative* perspective identified the following five types of systems engineers based on observations of their ability to deal with problems and solutions (Kasser, et al., 2009).

- ***Type I: apprentices*** who have to be told "how" to implement the solution system.
- ***Type II: imitators/doers.*** This type is the most common type of systems engineer. Type IIs have the ability to follow a process to implement a physical solution system once told what to do.
- ***Type III: problem solvers.*** Once given a statement of the problem, this type has the expertise to conceptualize the solution system and to plan the implementation of the solution, namely create the process to realize the solution.
- ***Type IV: problem formulators.*** This type has the ability to examine the situation and define the problem (Wymore, 1993) page 2), but cannot conceptualise a solution.
- ***Type V: engineer-leaders, pathfinders or innovators.*** This type is rare and combines the abilities of the Types III and IV, namely has the ability to examine the situation, define the problem, conceptualise the solution system and plan and manage the implementation of the physical solution.

### 5.5 Assessment of cognitive skills

The cognitive skills of students may be assessed using:

1. The updated Bloom's taxonomy (Overbaugh and Schultz, 2013) shown in a pyramid format in Figure 14.
2. Existing ways of measuring critical thinking. A literature review showed that the problem of assessing the degree of critical thinking in students seemed to have already been solved by several different people in several different ways, e.g. (Facione, et al., 2000; Eichhorn, 2002; Wolcott and Gray, 2003; Allen, 2004; Paul and Elder, 2006; Perry, 1981; Gordon G. et al., 1974; Gharajedaghi, 1999). Perceptions from the *Generic* perspective showed that Wolcott and Gray's method for assessing a critical thinking level was very similar to that used by Biggs for assessing deep learning (Biggs, 1999). Since a modified version of Biggs criteria had been used successfully at the University of South Australia (UniSA) (Kasser, et al., 2005) for assessing student's work, Wolcott's method was selected (Kasser, 2013b).

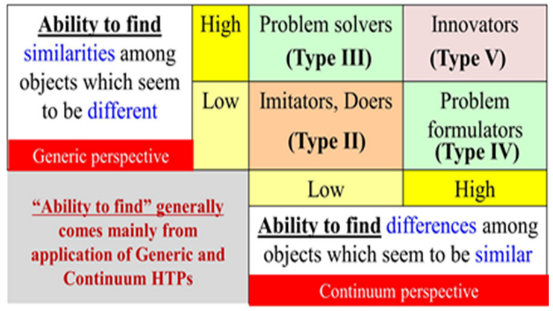


***Figure 15 Matching cognitive skills to the five types of systems engineers***

Gordon et al. provided a way to identify the difference in cognitive skills between innovators, problem formulators, problem solvers and imitators (Gordon G. et al., 1974). The difference shown in Figure 15 which is based on a table in Gordon et al. (Gordon G. et al., 1974) as cited by (Gharajedaghi, 1999) is based on:

- Ability to find ***differences*** among objects which seem to be ***similar.***
- Ability to find ***similarities*** among objects which seem to be ***different.***


***Figure 14. Updated Bloom's taxonomy (Overbaugh and Schultz, 2013)***

The differences in the '***ability to find*** …' leads to the different types of personalities. For example,

- ***Problem formulators*** score high in ability to find differences among objects which seem to be similar.
- ***Problem solvers score*** high in ability to find similarities among objects which seem to be different.

From a slightly different perspective, Gharajedaghi discussed four personality types based on the same abilities in the context of separating the problem from the solution (Gharajedaghi, 1999) pages 116-117) where:

- ***Leaders and pathfinders*** (innovators in Figure 15) have a holistic orientation to **seeing** the bigger picture and putting issues in the proper perspective.
- ***Problem solvers*** are **scientifically** oriented with a tendency to find similarities in things that are different. They are concerned with immediate results.
- ***Problem formulators*** are artistically oriented having a tendency to find differences in things that are similar. They are concerned with the consequences.
- ***Doers*** are practitioners producing tangible results following established processes.

Four of the five types discussed in Section 5.4 were then matched to the factors conducive to innovation as shown in Figure 15. Note, Type IIs tend to:

- Rate low in their ability to identify similarities among objects that appear to be different as well as their ability to identify differences among objects which seem to be similar.
- Look for patterns and follow the process for dealing with the pattern.

### 5.6 Student attention span

Student attention span is a factor that must be considered in the design of a lecture since if the students are not paying attention there is little point in speaking. Studies in the UK in the late 1940s and 1950 in classes teaching technical topics associated with repairing communications equipment produced the graph shown in Figure 16 (Mills, 1953) page 32). The students tend to be more attentive at the start of a lecture, as shown in Figure 16 so the effectiveness of the lecturing decreases over time[53]. Accordingly, even with the use of slides that reset the attention span, student attention span needs to be reset at least every ten minutes, preferably sooner. This also means that a break should be taken after an hour or so. If one is not taken, after an hour and half, there is a good probability that at least one person will need to answer the call of nature. If they are counting down the seconds till the break because they do not wish to disturb the class, they are not learning. Mills also discusses the way time should be allocated in the classroom based on data from providing training during World War II. Mills presented the data shown in Figure 4 (Mills, 1953) page 39).

### 5.7 Three types of propositional knowledge

While knowledge may be classified in many ways, the following three types of propositional knowledge (Woolfolk, 1998; Schunk, 1996) page 166) provide a useful content-free classification useable in all pedagogies and domains:

1. ***Declarative knowledge:*** knowledge that can be declared in some manner, e.g. facts, subjective beliefs and organised passages. It is “knowing that” something is the case. For example, describing a process is declarative knowledge.
2. ***Procedural knowledge:*** knowing how to do something. It consists of rules and algorithms and must be demonstrated. For example, performing a process demonstrates procedural knowledge.
3. ***Conditional knowledge:*** knowing when and why to tailor and apply the declarative and procedural knowledge and why it is beneficial to do so.

Research findings showed that there is a general tendency to focus on teaching Declarative and Procedural knowledge and minimise teaching Conditional knowledge. However, in order to meet the requirements in Section 5.1 the pedagogy needs to provide the students with the opportunity to use Conditional knowledge, namely exercise the higher levels in the updated Blooms taxonomy.

The general tendency to focus on teaching Declarative and Procedural knowledge and minimise teaching Conditional knowledge may be because:

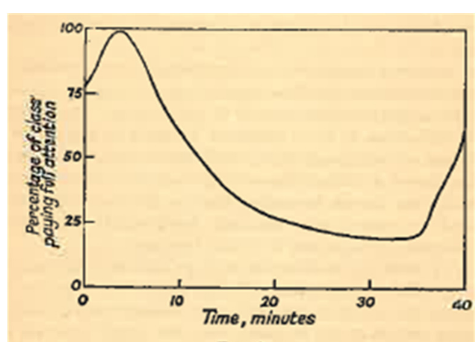


*Figure 16 Attention span (Mills, 1953)*

1. Many students with little work experience in higher positions in the organisation do not realise that they need Conditional knowledge in the real world.
2. When exercising Conditional knowledge there is generally more than one acceptable solution and many students are uncomfortable with not having a single correct solution

[53] Conference sessions may have been originally limited to 20-40 minutes for this reason.

or model answer.

3. Uncomfortable students tend to give their instructors poor evaluations at the end of the semester. Hence instructors who want good student evaluations to meet tenure requirements tend to focus on problems with a single correct solution or model answer.
4. Applying Conditional knowledge means that the students need to understand the knowledge which takes more work than memorization. Consequently, the class is a harder class than one that just requires memorization.
5. Based on observations of a number of classes at UMUC[54], students tend to give higher evaluations to easy classes than to harder classes. Hence instructors who want good student evaluations to meet tenure requirements tend to make the classes easy and focus on Declarative and Procedural knowledge.

After experiencing the balanced classroom pedagogy, particularly the Authentic Learning Environment discussed in Section 5.9, students tend to realise that they need the Conditional knowledge in the real world and that reflects in the good student evaluations of the balanced classroom pedagogy discussed in Section 9.

### 5.8 Skills and competencies

The literature also contains a number of suggestions for what should be incorporated into the classroom pedagogical experience[55]. For example:

- Brown and Scherer suggest incorporating the following features into the classroom experience (Brown and Scherer, 2000):
    1) Use of open-ended problems.
    2) Encouragement/development of student creativity.
    3) Use of the systems design methodology.
    4) Consideration of alternative solutions.
    5) Detailed system design specifications.
    6) Use of decision methodologies.
    7) Consideration of feasibility, reliability, and maintainability.
    8) Inclusion of economic, social, ethical, aesthetic, and economic impacts.
    9) Use of real problems with real clients.
- The American Society for Engineering Education (ASEA) provided the following list of ingredients associated with reshaping the curriculum (Sage, 2000) citing (ASEA, 1994).
    1) Team skills, collaborative and active learning.
    2) Communication skills.
    3) A systems perspective.
    4) An understanding and appreciation of diversity.
    5) Appreciation of different cultures and business practices, and understanding that engineering practice is now global.
    6) Integration of knowledge throughout the curriculum a multidisciplinary perspective.
    7) Commitment to quality, timeliness, continuous improvement.
    8) Undergraduate research and engineering work experience.
    9) Understanding of social, economic, and environmental impact of engineering decisions.
    10) Ethics.

[54] The author's and those of other instructors observed as part of the author's duties a Program Director.
[55] However, the literature rarely shows how to incorporate the suggestions.

- Charyton and Merrill cite (Felder, 1987) and (Isaksen and Parnes, 1985) stating that to develop and nurture critical and creative problem solving skills, we must provide opportunities for students to exercise those skills. open-ended questions, problem finding, fluency (quantity of solutions) flexibility (variety of solutions) and originality are vital components towards enhancing analysis and synthesis of information learned (Charyton and Merrill, 2009) .
- The seven elements of good practice in undergraduate education (Chickering and Gamson, 1991) which are as follows:
    1) ***Encourages student-faculty contact.*** By virtue of discussing the requirements ahead of time and discussing both content and style of presentation after the presentation.
    2) ***Encourages cooperation among students.*** By virtue of working in teams.
    3) ***Encourages active learning.*** After the initial passive learning (reading) they then spend most of the time understanding, processing and presenting the information[56].
    4) ***Gives prompt feedback.*** By virtue of the instructor's comments immediately after a presentation.
    5) ***Emphasizes time on task.*** By limiting the actual presentation time and suggested preparation time.
    6) ***Communicates high expectations.*** By virtue of the requirements. I have found that when high expectations are set, high performance follows.
    7) ***Respects diverse talents and ways of learning.*** The students do it their way.

### 5.9 Real world scenarios

One way to meet Enger's challenge is to add the opportunity to gain experience by including real world scenarios in a class in the form of an Authentic Learning Environment which has the following ten design characteristics (Felder, 1987) cited by (Isaksen and Parnes, 1985):

1. Authentic activities have real-world relevance.
2. Authentic activities are ill-defined, requiring students to define the tasks and subtasks needed to complete the activity[57].
3. Authentic activities comprise complex tasks to be investigated by students over a sustained period of time.
4. Authentic activities provide the opportunity for students to examine the task from different perspectives, using a variety of resources.
5. Authentic activities provide the opportunity to collaborate.
6. Authentic activities provide the opportunity to reflect.
7. Authentic activities can be integrated and applied across different subject areas and lead beyond domain-specific outcomes.
8. Authentic activities are seamlessly integrated with assessment.
9. Authentic activities create polished products valuable in their own right rather than as preparation for something else.
10. Authentic activities allow competing solutions and diversity of outcome.

The requirements for the Authentic Learning Environment contain many of the requirements listed in the previous sections particularly those in Sections 5.2 and 5.8 however, space limitation precludes the discussion of the remaining traceability.

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[56] But sometimes not in this order.

[57] Students complain about the vagueness in the first exercise. The volume of complaints then tends to decrease during the semester.

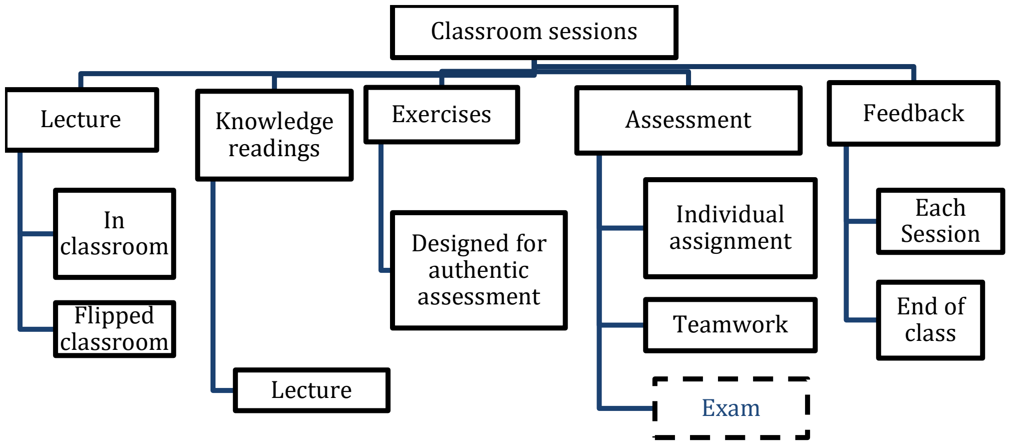


*Figure 17. The balanced classroom (integrated system)*

# 6 The architecture of the balanced classroom

The architecture of the balanced classroom is shown in Figure 17. It contains a mixture of subsystems from two cognitive theories of learning: lecture-centric (objectivist) and exercise-centric (constructivist) (Jonassen, 1991)[58]. Briefly consider each of the following subsystems:

1. The student teams discussed in Section 6.1
2. The lecture discussed in Section 6.2.
3. The flipped classroom discussed in Section 6.3.
4. The knowledge readings discussed in Section 6.4.
5. The exercises discussed in Section 6.5.
6. The assessment discussed in Section 6.6.
7. Feedback discussed in Section 6.7.

## 6.1 The student teams

The student team is a vital component since much of the learning is done in teams before, during and after the classroom session.

### *6.1.1 The team forming exercise*

The students self-select teams in the first session of each class according to the following instructions:

1. Form teams
2. Consider forming your team as a project
3. Present (<5 min) a summary of:
    1) The activities performed to create the team.
    2) Team members including team leader.
    3) How team complies with requirements for team members discussed in Section 6.1.2.
    4) Lessons learned from process.
    5) How the process might be improved.

[58] The objectivist approach is based on the assumption that there is a real, objective, and knowable world, and that the instructor's primary duty is to convey that knowledge to the students. The constructivist approach, on the other hand, is based on the assumption that knowledge is constructed by the learner, that learning is active and collaborative and that the instructor's primary duty is to provide a context whereby the student can discover his or her own "constructed" knowledge.

This exercise requires the students to do something and then reflect on it.

Once the presentations are over the instructor can use the exercise for several learning opportunities including:

- Explaining the reasons for the requirements discussed in Section 6.1.3.
- Explaining that the purpose of the exercise has to be understood in order to improve the process, and the exercise had several purposes including:
  - Forming teams
  - Acting as an icebreaker allowing the student to get to know other students.
  - Showing the effect of not communicating with the customer as discussed in Section 6.1.3.
  - An example of how to present information in a clear and concise manner in the presentation as shown in Table 11 which clearly shows an instance of team compliance to the requirements. Most teams state the requirement has been met without showing how it was met even when making presentations in PowerPoint or using flipcharts. The table makes it very clear so the audience does not have to think about how the team complies with the requirements and can concentrate on the presenter's words.

### *6.1.2 The requirements for team members*

It has been reported that, "*When students self-select into teams, the best students tend to cluster, leaving the weak ones to shift for themselves, and friends cluster, leaving some students out of groups and excluding others from cliques within groups*" (Felder and Brent, 2007). This student tendency had been noted at UMUC and requirements for team membership to minimize this situation, improve the team and serve the purposed of demonstrating the effect of assumptions and failure to communicate with the customer were developed. The initial set of requirements comprised the first eight requirements. The last two were added as a result of innovative solutions in one smarter than average class. The current set of requirements is:

***Table 11 Team compliance to requirements***

| | **Sex** | **Laptop** | **Y/M** | **Org** | **Country** |
|---|---|---|---|---|---|
| **Joe** | M | Y | Y | ADT | Australia |
| **Linda** | F | Y | M | QET | UK |
| **Tom** | M | Y | Y | RBU | China |
| **Fred** | M | Y | Y | ADF | Singapore |
| **David** | M | Y | M | DSF | Singapore |

1. More than 3 and less than 7 people.
2. At least 1 male.
3. At least 1 female.
4. At least 1 with a laptop personal computer (PC).
5. At least 1 young.
6. At least 1 mature.
7. Less than 2 from the same part of company or organization.
8. Less than 2 from the same [birth] country (except Singapore).
9. All team members have to be present in room.
10. A specific person may not be in more than one team.

### *6.1.3 The reasons for the requirements*

The reasons for the requirements are as follows:

- Requirement 1 ensures a workable team by specifying a minimum and maximum number of students in the team. The use of two requirements shows the students how splitting the requirements into a single requirement per statement make it easy to comply with the requirement.
- Requirements 2 and 3 ensure that there is at least one male and one female on each

team because males and females approach problems in different ways. In situations where there are fewer females than teams, most of the teams do not ask for a waiver of the requirement but assume it. This provides an opportunity to discuss:

  - The result of not communicating the change to the customer and ending up with the wrong system, a failed project and an unhappy customer.
  - The reasons for the milestone reviews in the System Development Process (SDP) to preclude these types of assumptions; an example of the risk management built into the SDP.

- Requirement 4 is usually interpreted as the need to have a laptop in the room to use in exercises. In more than one continuing education class taught at the customer location, participants have left the room during the exercise to collect a lap top PC from their office. Since the requirement does not specify the location of the laptop. This requirement provides a learning opportunity to explain the nature of assumptions and how assumptions drive the work and can also lead to project failures or additional unrequired work which must be paid for in some manner.
- Requirements 5 and 6:
  - Ensure at least one young and one mature team member because young and mature (based on age and experience) view things differently.
  - Illustrate the effect of ambiguity in requirements (vagueness in specifications). In many of the classes the students assume values for young and mature and do not communicate those assumptions to the customer (the instructor). In the case when a student does ask for clarification at the start of the exercise, the student is commended on asking a good question; the teams are then instructed to assume a value to allow the effect of assumptions to be experienced and explained as per Requirement 4. Students had used age, experience and appearance to define young and mature.
- Requirements 7 and 8 are there to provide cultural difference in perspective and also in many cases illustrate the effect of assumptions that the requirement can be waived without notifying the instructor.
- Requirements 9 and 10 were added to preclude innovative solutions to the initial eight requirements.

### 6.2 The lecture

- Can be delivered in real-time in the face-to-face or distance mode classroom or pre-recorded for viewing before the session begins in what has become known as the “flipped classroom”.
- Can summarise session material, highlight the main points and add additional material pertinent to the session.
- Should contain knowledge **not** in the readings. If the lecture summarises the readings, the students will tend treat the lecture as providing a summary of the readings and tend not read the readings themselves[59].
- May be, or may include, a live or virtual guest speaker. For example, Professor Derek Hitchins provides some interesting and educational videos about systems engineering on his web site (www.Hitchins.net)[60] and on his YouTube video channel.
- May last as long as the students are willing to listen to it provided issues with student

[59] Over the years, several students have requested (the Cliff Notes) summaries of the lectures to save them to listen to the full lecture.
[60] In one class session he was even available by prior arrangement to accept and respond to questions by the students after the presentation.

attention span discussed in Section 5.6 are addressed.

### 6.3 The flipped classroom

As mentioned in the discussion on SC 2 in Section 3.2, the flipped classroom (Bergmann and Sams, 2012) is:

- Generally based on using a pre-recorded video of the lecture in the synchronous face-to-face environment which is an incomplete implementation of inverted learning (FLN, 2014) .
- A face-face classroom and a synchronous online classroom session in which the:
  1) Instructor pre-records the lecture and uploads it to the class web site.
  2) Students (are required to) view the lecture before the classroom session.

Time saved by not lecturing in the classroom session is to be used for exercises and other participative activities. However, although the use of the flipped classroom has shown an improvement in learning, see (Chao, et al., 2015) and similar for details, the pre-recorded lecture limited implementation of the flipped classroom is a non-systems approach to improving the learning environment, and suffers from at least two defects since the pre-recoded video lecture is Based on the incorrect assumption that all the students will view the lecture before class. Unfortunately, experience has shown that students treat the pre-recorded lecture in a similar manner to the way they treat the traditional readings; some read the material ahead of class and some do not, where:

1. Good students interested in the topic do tend to view the lecture before the class.
2. Poor students who need to view the lecture before class tend not to view the lecture before the class[61.]
3. Students who expect the instructor to tell them everything they need to know to pass the class in the classroom tend not to view the lecture before the class.

Most of the asynchronous lectures in Massive Open Online Classes (MOOCS)[62] tend to be shorter than 10-15 minutes. This seems to correlate to the attention span limit in Figure 16. However, there is a big difference between a lecture in the classroom and a pre-recorded lecture, namely the students are in control in the pre-recorded environment. They can start and stop the lecture at will according to their individual attention span, interruptions and other distractions. Consequently, as long as the lecturer does not drone on and on, talking about a single slide and changes slides often enough to reset the attention span, there does not seem to be a minimum lecture time requirement. For example, as summarised in Table 4:

- CSMN 648 at UMUC was an asynchronous online class. The first year the class ran with pre-recorded lectures was in 1998. The lectures ranged from 22 to 61.5 minutes with an average time of 38.36 minutes. Student feedback was positive, they liked the ability to replay the lectures and listen while commuting to work.
- Almost two and a half decades later, the pre-recorded lectures in the online Missouri University of Science and Technology (MS&T) SysEng412 class (Section 4.12) and the face-to-face MT5014 and various iterations of the face-to-face SDM5004 at NUS ranged between 6 and 79 minutes. Student feedback was also positive, the students with English as a second language specially liked the ability to replay the lecture.
- The first two lectures in SysEng412 were synchronous and were delivered in real

[61] Tested in practice by loading the lecture as PowerPoint slides and MP3 audio files. When instructions for the weekly exercises and assignments were inserted in the audio portion of the lecture some students did know about the instructions.
[62] Based on a limited sample of Coursera MOOCs.

*Table 12. Subsystem contributions to the ability to understand, manage, and solve technological problems*

| Ability | Lecture | Exercises | Knowledge readings |
|---|---|---|---|
| Multiple solutions to a problem/ requirement | Listened | Experienced | Experienced examples |
| Oral communications | - | Experienced | Experienced |
| Graphical/pictorial communications | Received | Experienced | Experienced |
| Ability to handle open-ended/ill-defined problems | - | Experienced | - |
| Systems thinking | Listened | Went beyond | Went well beyond |

time. However, when problems were reported with the audio and the technical support indicated that it was a common problem with instructors outside the continental USA, the problem of improving the quality of the lectures was dissolved by prerecording them as per CSM648 fifteen years earlier but using a different technology.

There is one advantage to chunking the lecture in a number of files. It allows individual chunks to be updated each time the class runs if the content:

- Becomes out-of-date.
- Needs to be clarified or otherwise updated for any other reason

### 6.4 The knowledge readings

The knowledge readings (Kasser, 2013b):

- Provide the students with the best way to learn according to Figure 5.
- Overcome the situation in which the students do not read the material ahead of time.
- Require the students working in teams, to read the material assigned to the session before the session and present:
    1) A summary of the reading.
    2) A list of main points.
    3) A description of one of the main points.
    4) Comments and reflections on the knowledge in the readings.
- Enable the instructor to correct any misinterpretations as they arose rather than find out something was misinterpreted in the assignment or examination at the end of the class.
- Provide three of the five top aspects of the engineering design process that best equip secondary students to understand, manage, and solve technological problems (Wicklein, et al., 2009) as shown in Table 12.
- Allow students to exercise cognitive skills at levels 3-6 of the upgraded version of Bloom's taxonomy shown in Figure 14.
- Absolved the problem of designing exercises to allow the students to progress through the six levels of the updated Bloom's taxonomy shown in Figure 14 This is because the treatment of the knowledge readings advances the students through the higher levels of the updated Bloom's taxonomy while the exercises only need to be designed for the lower levels. However, a thinking subsystem component was still added to the exercises as discussed in Section 6.5.
- Provide students with the opportunity to practice presentation skills in an Authentic Learning Environment and obtain feedback on both content and style.
- Demonstrate to the students that different people perceive information differently.
- Allow the students the freedom to contribute to the learning via their own learning style. For example, those that prefer:
    - ***Reading*** can read the material.
    - ***Hearing*** can use voice to text technology to listen to the readings.

- ***Interaction*** can do so within their team and the full class discussion following the set of presentations in each session.
- ***Researching and self-seeking*** can do so.

### *6.4.1 Requirements for the Knowledge Readings*

The requirements for the knowledge readings have evolved[63] to the following:

1. Summarize content of the reading (<1 minute).
2. List the main points (<1 minute).
3. Prepare a brief on two main points.
4. Brief on one main point (<1 minute per point).
5. Reflect and comment on reading (<2 minute).
6. Compare content with other readings and external knowledge.
7. State why you think the reading was assigned to the session.
8. Summarize lessons learned from the session and indicate source of learning; e.g. readings, exercise, experience, etc. (<2 minutes).
9. Use a different team leader for each session.
10. Presentation to be less than 5 minutes.

Consider each requirement:

1. ***Summarize content of reading.*** The requirement is to facilitate developing the skills to condense the information in the reading and hide (abstract out) details.
2. ***List the main points.*** This requirement requires the students to analyze and evaluate the knowledge (Blooms Taxonomy Levels 4 and 5) to identify and prioritize the main points.
3. ***Prepare a brief on two main points.*** The next requirement, requirement 4 is for the team to brief on one main point. However, once a team has made a briefing, there is the possibility that another team will want to brief the same main point. This requirement requires the students to read two main points in the text and allows the option for the instructor to bypass some of the potential repetition.
4. ***Brief on one main point.*** This requirement helps to limit the time for the presentation and minimizes repetition.
5. ***Reflect and comment on reading.*** This requirement invokes the higher level cognitive skills by requiring the students to apply, analyse, evaluate and create knowledge (Blooms Taxonomy Levels 3 to 6).
6. ***Compare content with other readings and external knowledge.*** This requirement:
    - Invokes the higher-level cognitive skills by requiring the students to apply, analyse, evaluate and create knowledge (Blooms Taxonomy Levels 3 to 6).
    - Encourages students to research similar material to the assigned readings and compare and contrast the material.
    - Encourages students to make connections between the various readings allocated to a session, developing their ability to see similarities and differences in the assigned and external readings.
    - Helps to identify and develop students with problem solving and problem formulating skills by requiring the student to apply the *Generic* and *Continuum* holistic thinking perspectives as discussed in Section 5.5. This is where the students can develop and apply their:
        - Ability to find differences among objects which seem to be similar.

[63] The evolution is discussed below together with the results.

- Ability to find similarities among objects which seem to be different.

Both Gordon et al. (Gordon G. et al., 1974) and Gharajedaghi (Gharajedaghi, 1999) discuss the same abilities in the context of separating the problem from the solution, critical cognitive skills for both systems engineers and project managers. These skills involve more than systems thinking

7. ***State why you think the reading was assigned to the session.*** This requirement also invokes the higher level cognitive skills by requiring the students to apply, analyse, evaluate and create knowledge (Blooms Taxonomy Levels 3 to 6). The similarities and differences in this part of the presentation illustrate to the students that different people can draw similar and different conclusions from the same data. In a number of instances students have drawn innovative applicable conclusions.
8. ***Summarize lessons learned from the session and indicate source of learning.*** This requirement also invokes the higher-level skills by requiring the students to apply, analyse, and evaluate knowledge (Blooms Taxonomy Levels 3 to 5).
9. ***Use a different team leader for each session.*** This requirement minimizes the workload on students who tend to be perfectionists and undertake to do most of the team work themselves to compensate for poor performance by individuals.
10. ***Presentation to be less than 5 minutes.*** This requirement puts an upper limit on the length of the entire presentation. This requirement also forces the students to think about prioritizing the information they wish to communicate.

Each team designs its own solution to the requirements and may choose to meet the knowledge reading requirements as a group splitting the material between team members or delegate the entire knowledge reading presentation to one or more members of the team. However, the grade is assigned to the entire team. The teams may elect to use a single presenter or multiple presenters in each session.

Recognising that part-time postgraduate students have other demands on their time, each team has one wildcard that allows them to skip the knowledge reading presentation for a session. The wildcard may be declared at, or before, the time the presentation is due. The wildcards have been used when the students are busy with mid-term examinations in other classes, when there are a lot of readings for a specific session, when the designated knowledge reader was unable to prepare the presentation or for the last session. In the event that all teams use the wildcard in the same session the instructor has the choice to skip or present the lecture[64].

### 6.5 The exercises

The exercises:

1. Were developed in the immersion course described in Section4.11.
2. Are designed so that the students:
    - Apply the knowledge from the session to produce a product (the presentation); namely the lower levels of the updated Bloom's taxonomy.
    - Have to think about, and present, what they have learned in doing the exercise by virtue of the exercise requirement to present a 'lessons learned' element; namely the higher levels of the updated Bloom's taxonomy.
3. Take place in the context of an authentic representation of workplace and consequently are designed to comply with the requirements for an Authentic Learning Environment listed in Section 5.9. For example, in the first half of the project management

[64] This situation has not occurred in the five years of using knowledge readings.

class (SDM5004), the students developed the staffing, cost and schedule estimates for an information technology system upgrade project. In the second half of the class the students had to deal with the effect of "events"[65]. Typical events were:

- Company won a major contract for a new and exciting project, 50% of all technical and managerial staff applied for transfer to new project.
- Customer's budget has been reduced by 25% for the rest of project.
- Project manager was severely injured in automobile accident and was on medical leave for ten time periods[66].
- Poor engineering resulted in delay of five time periods in the task requiring the most time.
- Poor engineering resulted in delay of five time periods in the most costly task.
- Innovative engineering reduced project costs by 10%.
- Vendor/manufacturer of the most critical subsystem went bankrupt and cannot deliver.

4. Are an authentic simulation of the real world (Auman, 2011) in which the students carry out a the types of tasks they would be doing in the workplace providing them with the accelerated experience which cuts down the time to become a systems engineering. As a second example, in the systems engineering class some of the sessions cover the states of the system lifecycle. The exercises in those sessions require the students to perform the activities that systems engineers do in those states of the system development process in the real world.
5. Provide the remaining two of the five top aspects of the engineering design process that best equip secondary students to understand, manage, and solve technological problems (Wicklein, et al., 2009) as shown in Table 12.
6. Provide the ability to handle open-ended/ill-defined problems (Wicklein, et al., 2009) and systems thinking by the nature of the structure of the exercise by often requiring students to define problem first before mitigating it[67]. For example in the systems engineering class in the Defence domain, an exercise begins with a short video of a military Unmanned Aerial Vehicle (UAV) operational scenario followed by the statement, "*The UAV needs to be improved, brainstorm the situation and propose improvements*". The students then have to decide which aspect of the UAV to improve, hence formulating their problem. One interesting, informative and educational (to the students) outcome is that different teams formulate different problems showing the need for frequent discussions between the customer and the developer.
7. Give students the choice to have a single presenter or different presenters for different sections of the presentation and both types of presentations have been made.
8. Have multiple acceptable solutions rather than a single correct solution.
9. Require application of domain knowledge and cognitive skills.
10. Are sized for the required workload; the time the students are expected to allocate to the session[68].
11. Can take place inside the classroom session or outside the classroom session depending on the delivery mode.

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[65] Not typically taught in project management classes which focus on creating the plans.

[66] The generic 'time period' may be a day, a week or a month depending on the project. The students convert the time period as appropriate.

[67] The feedback from the first exercise in a class often contains complaints of 'vagueness' in the exercise instructions. By the end of the class there are no complaints of vagueness. So, either the students have learnt to deal with vagueness or they have given up complaining.

[68] Although the students generally put in more time, at least in the early classes

### 6.6 Assessment

Authentic assignments in the postgraduate courses tended to require the students to apply the knowledge to perform a task discussed in the semester. Thus, for example, the focus of the assignment in a class in software maintenance was to produce a maintenance plan. The assignment however did not allow an assessment to be made as to the understanding of the knowledge. It was noticed in some corporate postgraduate courses at UniSA that it was possible for students to gain high grades in a course without demonstrating a grasp of the application of the subject matter. Students could even fail to complete the assignment and still pass the course (albeit with a minimum passing grade). When the assessments were changed from using the declarative knowledge taught in a class to commenting and reflecting on the knowledge taught in the class, to an approach applying Bloom's taxonomy levels adapted from Biggs (Biggs, 1999) the grades fell into line with the student's in-class demonstrated abilities. Examples of such changes are:

- ***Project Development:*** instead of being asked to produce a Project Development Plan, students are asked to "describe, compare, and contrast the way project development is performed in Government and Private Industry."
- ***Requirements Engineering:*** instead of being asked to produce a requirements document, students are asked to "discuss the nature of requirements, their use in the acquisition life cycle by the government, and ….".

Now universities tend to teach generic principles; employers tend to want company-specific principles taught. The compromise is to teach generic principles in the classroom and set up assignments in which the students compare, contrast, comment and reflect on, the generic principles with the company specific ones.In a postgraduate class the emphasis shall be on the application of knowledge; critical thinking and the updated Bloom's taxonomy levels 3 and above, rather than on levels 1 and 2 (memorization). The assessment in the balance classroom is in three parts based on:

1. Individual performance during the semester.
2. Teamwork in the exercises and knowledge readings.
3. An individual final examination.

The correspondence between the updated Bloom's taxonomy levels, the ability tested in the knowledge readings, exercises and assignments is shown in Table 13 adapted from Overbaugh and Schultz (Overbaugh and Schultz, 2013). The balanced classroom assignment required the students to write an essay containing both descriptive (Declarative knowledge) and critical thinking (Conditional knowledge) elements. In most classes although students were given the opportunity to submit a draft for comment and review before submitting a final version for grading, few students did so[69]. Students demonstrating the lower levels of cognitive skills also seem to turn in incomplete assignments (which contribute to the low grade due to lack of content to assess) even though they had been told in several ways in different sessions what content the assignment needed to cover.

If examinations are used they shall use well-written multiple choice questions which require the students to exercise the higher level cognitive skills (Conditional knowledge discussed in Section 5.7).

### 6.7 Feedback

[69] In one class, 35 out of the 42 students in the class did not avail themselves of the opportunity.

*Table 13. Grading based on cognitive skills according to the modified Bloom's taxonomy*

| Grade | Taxonomy level | | Ability being tested | Demonstrating skill by … |
|---|---|---|---|---|
| A+ | 6 | Creating | Can the student create a new product or point of view? | Assembling, constructing, creating, designing, developing, formulating, writing |
| A | 5 | Evaluating | Can the student justify a stand or decision? | Appraising, arguing, defending, judging, selecting, supporting, valuing, evaluating |
| B+/B | 4 | Analysing | Can the student distinguish between the different parts? | Appraising, comparing, contrasting, criticizing, differentiating, discriminating, distinguishing, examining, experimenting, questioning, testing |
| B- | 3 | Applying | Can the student use the information in a new way? | Choosing, demonstrating, dramatizing, employing, illustrating, interpreting, operating, scheduling, sketching, solving, using, writing |
| C+ | 2 | Understanding | Can the student explain ideas or concepts? | Classifying, describing, discussing, explaining, identifying, locating, recognizing, reporting, selecting, translating, paraphrasing |
| C | 1 | Remembering | Can the student recall or remember the information? | Defining, duplicating, listing, memorizing, recalling, repeating, reproducing, stating |

Feedback from the students to the instructor takes place the form of:

1. The traditional end of class student evaluation.
2. Sessional feedback.
3. Comments on content and style of student presentations.

Consider each of them.

- ***The traditional end of class student evaluation:*** which has evolved into an online survey tool providing the students with a number of questions. The students respond to each question on a 5-point Likert scale. The survey at NUS also requests free-form comments about the class and the instructor. Other open ended questions the author has used in classes and workshops outside NUS include:
    - What was the best part of the workshop?
    - What was the worst part of the workshop?
    - The three most useful things I learned were …
    - The least useful thing I learned was …

    The answers to these questions provide valuable information leading to changes in the subsequent iteration of the class/workshop.

- ***Sessional feedback:*** The author was introduced to this form of feedback in a graduate teaching workshop at the George Washington University in 1989. At the end of each session the students are asked to take a small piece of paper and without writing their name or any identifying information, write down what they thought was the:
    - **B**est thing about the session.
    - **W**orst thing about the session.
    - **M**issing: something they expected but was not there.
    - **Q**uestion(s) that they did not ask during the session.

    The students are also told that if nothing comes to mind in each category within 10 seconds, to leave it blank. The instructor collects the papers and types up the responses before the following session. This form of feedback is multi-purpose. For example, it:

    - Allows students who process information slowly to ask questions at the end of the session.
    - Sometimes shows that certain topics are both "best" and "worst" as perceived by different people.
    - Can prompt the instructor to improve parts of the session where the students had problems understanding the knowledge to make the subsequent iteration of the class more effective.
- ***Comments on content and style of student presentations*** have been discussed above in Section 6.4 for the knowledge readings and Section 6.5 for the exercises.

## 7 The three parts of each session

The three parts of each classroom session are discussed as follows.

1. Pre-session activities in Section 7.1.
2. In-class activities in Section 7.2.
3. Post-session activities in Section 7.3.

The post-session activities from one session may overlap the pre-session activities for the subsequent session.

### 7.1 Pre-session activities

The pre-session activities include:

- Reading the session material.
- Viewing the pre-recorded lecture.
- Preparing the knowledge reading presentations.

### 7.2 In-class activities

The in-class activities generally follow the following six-part sequence as of the second class meeting/session.

1. ***Discussion on sessional feedback from previous session:*** opens the class. The instructor shares the BWMQ feedback from the previous session and answers any questions that were posed[70]. Starting the class session in this manner also provides the opportunity to summarise the previous session as a lead-in to the current session.
2. ***Exercise presentations:*** the student teams present their responses to the exercises. The instructor immediately provides feedback as to the good and bad points and a grade. When each team has presented, the instructor leads a brief discussion comparing the presentations.
3. ***A short break:*** about ten to fifteen minutes, roughly half way into the session.
4. ***Knowledge readings:*** summarize the knowledge for the session. The instructor comments on and grades each presentation as soon as it is made. When each team has presented, the instructor leads a brief discussion comparing the presentations.

[70] Having had some time to think about the question and answer.

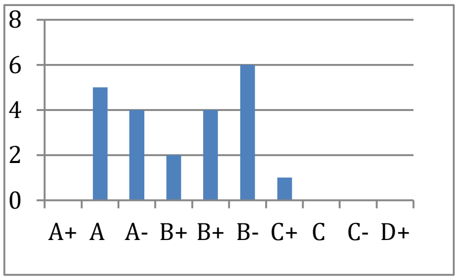


*Figure 18 Class demonstrating split cognitive skills*

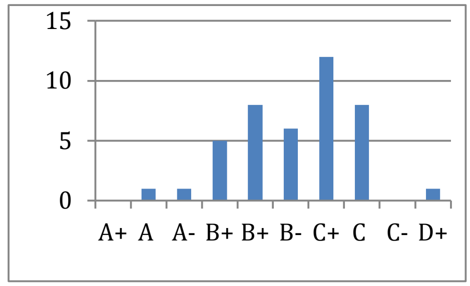


*Figure 19 Class demonstrating mostly lower level cognitive skills*

The students in each class typically have a different mixture of cognitive skills. The grading[71] performed according the information in Table 13 tends to reflect the behaviour of the students observed in the knowledge and exercise presentations, and interaction in the question and response dialogues. It was interesting to see the different students demonstrate the characteristics of the five types of systems engineers (Section 0). For example, the grades in one class where about half the students did not demonstrate the higher order cognitive skills were as shown in Figure 18. In another class where most of the students only demonstrated remembering and understanding (Taxonomy Levels 1 and 2) levels the grades were as shown in Figure 19.

Each presentation in each session differs; illustrating that there can be more than one correct/acceptable solution to a problem and there can be more than one way to satisfy a requirement.

5. ***The Lecture:*** The pre-recorded lecture was made available on the class website prior to the classroom session. However, sometimes students had questions on the material and sometimes there was intellectual property or other content that must not be uploaded to the web site but may be used in the classroom. So, the lecture was delivered in the classroom by presenting the PowerPoint slides silently, advancing the slides and pausing about two to five seconds on each slide and asking the students to call out when they had a question in the same way that it was done in MS&T SysEng412 discussed in Section 4.12.
6. ***Requesting the sessional feedback for the session:*** This is not done in the last session.

### 7.3 Post-Session activities

The post-session activities include:

- Doing the team exercise for the session.
- Preparing the exercise presentation to be made in the following session.

## 8 Incorporating the three types of knowledge

The pedagogy of the balanced classroom incorporates all three types of knowledge mentioned in Section 5.7. The students demonstrate their:

- Memorization of Declarative knowledge via the knowledge readings.
- Mastery of Procedural knowledge in what they do in the exercises.
- Mastery of Conditional knowledge by how they do the exercises and their reflections on what they did and learnt in the exercises.

[71] The individual grades are made up from a combination of team work and an individual assignment.

The students exercise their higher order cognitive skills by meeting the exercise requirement to reflect on the content of the knowledge presented in the knowledge reading and what they learned from the exercises. In many instances while they realise they are doing a lot of work, they don't realise what they have done and what they have learnt until it is been pointed out to them in the summary session at the end of the semester.

# 9 Results

The balanced classroom was used in its current format in postgraduate classes in project management, systems engineering and technology and innovation management at NUS in 2013 and 2014. The pedagogy of the balanced classroom:

- Employed effective teaching methods discussed in Section 5.3.
- Ignored learning styles due to the impossibility of matching learning and teaching styles in a typical systems engineering postgraduate class, the effect of learning styles was largely ignored other than to provide the opportunity for students to use their favourite style. Advantage of having three instructors in one class allowed some data to be collected on differences in teaching and learning classes as discussed in Section 4.8.

Consider the following observations from the use of the balance classroom.

## 9.1 The knowledge readings

Some of the results to requiring teams to present knowledge readings in postgraduate classes in systems engineering and project management, first by requirement and then generically, are:

### *9.1.1 Results by Requirement*

Perceptions from the results by requirement include:

1. ***Summarize content of reading.*** Results have shown that quite often different teams present different verbal summaries; even when the lists of items on the PowerPoint slide are the same. This illustrates to the students that different people pick up on different things in documents and the need to make sure that the reader indeed gets the message the writer intends to convey. Smarter students have also realized that an abstract and summary of a paper and the introduction and summary of a book chapter contain the information that needs to be presented in this part of their presentation. Sometimes other students brief the whole reading at this point demonstrating the inability to abstract the information[72].
2. ***List the main points.*** The differences in the presentations help to illustrate that different people will pick out different main points and rank them in different orders of importance. Often items that one team will list as a main point will be ignored by another team. For example, Figure 20, Figure 21, and Figure 22 show the main points presented by three teams in one systems engineering class in 2009. While the teams picked up on FRAT and SEGS-1, they listed them in different levels of importance and also disagreed on what was the third main point. This is an important lesson on the need to ensure that an audience interprets information in the desired manner and to take steps in the communications medium to mitigate the risk of misinterpretation.

   Sometimes students try to brief the whole reading at this point demonstrating the inability to abstract the information[14].

[72] This generally happens at the beginning of the semester and improves as a result of experience.

3. ***Prepare a brief on two main points.*** This requirement allows the student to demonstrate remembering and understanding (Blooms Taxonomy Levels 1 and 2). Experience (student feedback) has shown that too many presentations on the same topic tend to become boring very quickly so attention wanders and the students do not focus on the similarities and differences in the presentations. Requirements 3 and 4 were added to minimize repetition.

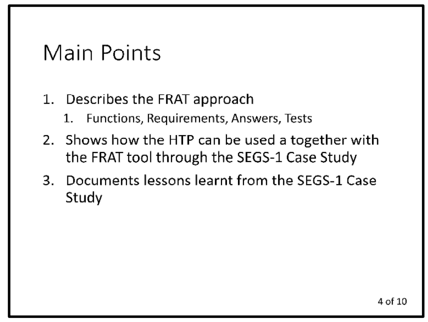

***Figure 20 Three main points***

4. ***Brief on one main point.*** This requirement helps to limit the time for the presentation and minimizes repetition. Before limiting the brief to one main point each team would brief on the entire reading which resulted in repetition as even when the students were instructed not to repeat information that had already been presented, they tended to do so. Too much repetition defeats the purpose as discussed above in Requirement 3.

    Experience has also shown that at least one brief in each semester will contain material based on the student misinterpreting or misunderstanding the knowledge in the reading. The instructor can correct the error in the session and reflect on how to present the material in the following iteration of the class in a better way.

    At the beginning of the semester most students tend to brief on the knowledge without reflection and comment understanding (Blooms Taxonomy Levels 1 and 2). After receiving feedback from the instructor many students can then reflect and comment on the reading which exercises the higher-level cognitive skills and minimizes repetition.

    Some students appear to be repeating the knowledge without understanding it. They stick to a prepared script, so even if another team has already presented the material, they restate it, and most of the time, do not refer to the same knowledge already covered in a previous presentation.

    Some students don't seem to be able to tell the difference between 'knowledge' and 'applying the knowledge'. The knowledge readings help the instructor to point out which goes where; i.e. knowledge in the knowledge readings and application in the exercise.

5. ***Reflect and comment on reading.*** Some students can do this right away, others have to learn and apparently some never do learn how to do this.
6. ***Compare content with other readings and external knowledge.*** This requirement

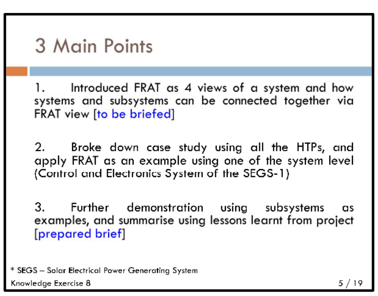

***Figure 21 Three diffent main points***

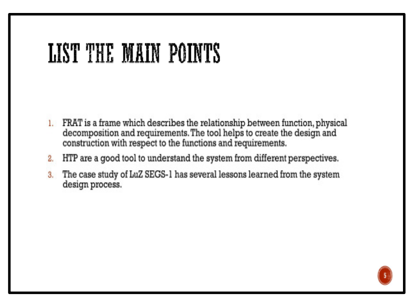

***Figure 22 Three more different main points***

makes the presentations more interesting. The students sometimes invoke web sites, journal articles and books, some of which are new to the instructor. The pertinence of the external knowledge also indicates the degree of understanding of the session knowledge. Students often relate anecdotes from their own experience in this part of their presentation.

7. ***State why you think the reading was assigned to the session.*** The similarities and differences in this part of the presentation illustrate to the students that different people can draw similar and different conclusions from the same data. In a number of instances students have drawn innovative applicable conclusions.
8. ***Summarize lessons learned from the session and indicate source of learning.*** Often the students state that a lesson was learnt during the team discussion; sometime the lessons learnt come from applicable prior experience and most often from the literature. The requirement to add the source of the lesson learnt was a modification because originally it was difficult to tell from the presentation if the lesson had actually been learnt or was just something being repeated from the text.
9. ***Use a different team leader for each session.*** This requirement minimizes the workload on students who tend to be perfectionists and undertake to do most of the team work themselves to compensate for poor performance by individuals. Some detail oriented dedicated team leaders have had to be counselled that sometimes people should be allowed to fail in a controlled environment, so that they hopefully will learn from the failure. Better to fail in the classroom than on-the-job.
10. ***Presentation to be less than 5 Minutes.*** This original requirement was 15 minutes. The requirement helps the students develop time management skills when the instructor allows the presentations to go over time and the class lasts an hour longer than scheduled. The students often seem surprised when the instructor points out that he is not their timekeeper. Most teams leant to manage the time and keep the presentation down to 15 minutes. In one class when the students could not manage the time, and consistently went overtime in every session, the time limit was reduced to 5 minutes at the beginning of one session and the students were given 30 minutes to modify their presentation. This change received positive comments from a number of the students in the feedback and was incorporated into the requirements for subsequent sessions and classes.

### *9.1.2 Generic perceptions*

Other perceptions include:

1. The knowledge readings provide three of the five top aspects of the engineering design process that best equip secondary students to understand, manage, and solve technological problems (Wicklein, et al., 2009)[73]:
   - Multiple solutions to a problem/requirement.
   - Oral communications.
   - Graphical/pictorial communication.

[73] The remaining top two, ability to handle open-ended/ill-defined problems and systems thinking are covered in the session exercise not described in this paper.

***Table 14 Class A extract from student evaluations***

| Q | Items evaluated | Faculty member average score | Department Average score | Faculty average score |
|---|---|---|---|---|
| 1 | The teacher has enhanced my thinking ability. | 4.333 | 4.142 | 3.959 |
| 6 | The teacher has helped me understand how to apply knowledge. | 4.333 | 4.089 | 3.947 |
| 7 | The teacher has enhanced my ability to learn independently. | 4.333 | 4.078 | 3.950 |
| 8 | Overall the teacher is effective. | 4.333 | 4.126 | 3.987 |

***Table 15 Class B extract from student evaluations***

| Q | Items evaluated | Faculty member average score | Department Average score | Faculty average score |
|---|---|---|---|---|
| 1 | The teacher has enhanced my thinking ability. | 4.500 | 4.205 | 3.958 |
| 6 | The teacher has helped me understand how to apply knowledge. | 4.375 | 4.100 | 3.946 |
| 7 | The teacher has enhanced my ability to learn independently. | 4.500 | 4.090 | 3.960 |
| 8 | Overall the teacher is effective. | 4.625 | 4.214 | 3.982 |

2. Each team presentation in each session differs; illustrating that there can be more than one correct/acceptable solution to a problem and to the systems engineers there can be more than one way to satisfy a requirement.
3. Student feedback is that while the classes incorporating knowledge readings are a lot of work they feel that they have learnt a lot and the classes are changing the way they think.
4. Students who are used to classes where they are lectured at, to need to be shown why the knowledge readings have been introduced[74]. This is generally done in the introductory session to the semester.
5. Student feedback is that while the classes incorporating knowledge readings are a lot of work they feel that they have learnt a lot and the classes are changing the way they think. Two extracts from student evaluations of two different classes are shown in Table 14 and Table 15. Table 14 is from a class on the systems approach to technology and innovation management in which the students were taught to think holistically. In the example, the class size was 18 and the number of students responding was 3 (17%). Table 15 is from a class on the systems approach to project management. In the example, the class size was 35 and the number of students responding was 8 (23%). So in this small sample of two classes on two very different topics, some of the students evaluated the contribution to improving their cognitive skills as being more effective than the approach used by any other teacher in the faculty.
6. Seven elements of good practice in undergraduate education (Chickering and Gamson, 1991) were identified while writing this paper. In systems engineering they can be used as test criteria. Accordingly, the knowledge readings incorporate these elements of good practice as follows:
    1) ***Encourages student-faculty contact.*** By virtue of discussing the requirements ahead of time and discussing both content and style of presentation after the presentation.
    2) ***Encourages cooperation among students.*** By virtue of working in teams.

[74] Hence this paper which will now be used as a reading for the introductory session.

3) ***Encourages active learning.*** After the initial passive learning (reading) they then spend most of the time understanding, processing and presenting the information[75].

*Table 16. Subsystem combination to Bloom's taxonomy*

| Bloom's taxonomy | | Lecture | Exercises | Knowledge readings |
|---|---|---|---|---|
| 6 | Creating | - | - | √ |
| 5 | Evaluating | - | - | √ |
| 4 | Analyzing | - | - | √ |
| 3 | Applying | - | √ | - |
| 2 | Understanding | Unknown | √ | √ |
| 1 | Remembering | Listened | √ | √ |

4) ***Gives prompt feedback.*** By virtue of the instructor's comments immediately after a presentation.
5) ***Emphasizes time on task.*** By limiting the actual presentation time and suggested preparation time.
6) ***Communicates high expectations.*** By virtue of the requirements. I have found that when high expectations are set, high performance follows.
7) ***Respects diverse talents and ways of learning.*** The students do it their way.

7. The contribution of the knowledge readings to exercising the cognitive skills in the modified Bloom's Taxonomy is summarized in Table 16. The students do not apply the knowledge when preparing and making their presentations, a gap covered by the authentic exercises component of the class not discussed in this paper.

### 9.2 The hybrid block-semester mode class

Running in June and August 2016 - details to be added

### 9.3 Other results and observations

Some of the other results and observations applicable to the exercise and knowledge reading presentations are:

- Team presentations in the same exercise and knowledge reading in each session differ illustrating:
  - There can be more than one acceptable solution to a problem.
  - There can be more than one way to satisfy a requirement.
- Students misuse bar charts, line graphs or pie charts and need to be shown when to use which type of chart. By comparing the information presented in the different charts students soon pick up on when to use which chart. For example, in one exercise two different teams presented the same information using different charts; one team used a stacked bar chart, the other used a radar or Kiviat chart as shown in Figure 23. This situation provided a good opportunity to discuss why different types of charts are best suited for displaying which types of data.
- Some students don't seem to be able to make connections between the different elements of the knowledge they are learning. They don't seem to be able to see connections between readings on the same topic, or between readings from the current session and readings from earlier sessions.
- Student presentations provide excellent 'learning opportunities' based on the mistakes the students make in content, style and format[76].
- Students like feedback on what was good and what was bad, but the bad has to be framed in a positive manner. So the instructor must provide positive feedback point-

[75] But sometimes not in this order.
[76] Students can make very innovative mistakes that even good instructors would not predict.

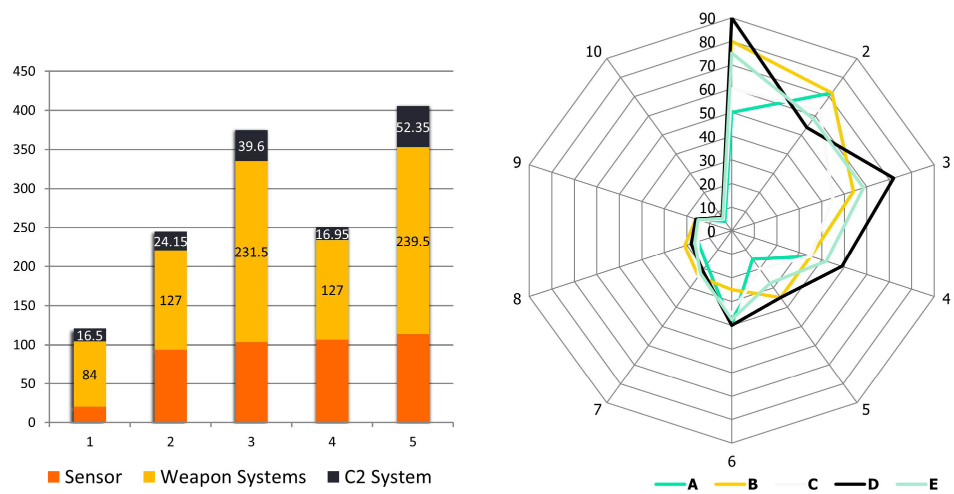


***Figure 23 Different ways of presenting the same information***

ing out where things were done well, and when providing negative feedback, must not only state that something was bad or wrong, but also add how to correct it or make it better[77].

- The quality of presentations by the different student teams improved as the semester progresses since better techniques for presenting information used by one team were picked up by other teams.
- The instructor can point that learning has taken place by showing the students how and why, with to reference to changes from their earlier presentations.
- Student reactions have been very positive once they overcame the initial shock of the different pedagogy[78].
- The post-class feedback was very positive on both the pedagogy and the knowledge the students feel they have gained. The comments are summarized as, "*It was a lot of work, but it was well-worth it*"[79].
- The subsystem contributions to:
    - The ability to understand, manage, and solve technological problems is summarized in Table 12.
    - Exercising the cognitive skills in Bloom's taxonomy is summarized in Table 16.
    - Creating an Authentic Learning Environment is in the exercise and knowledge readings.
- The compliance matrix showing how the combination of the subsystems of the balanced classroom complies with the system requirements is shown in Table 17.

## 10 Reflections and comments

In the passage of time since this research began:

1. Both the Dale Cone of Experience and the Learning Pyramid have been largely discredited as myths (Letrud and Hernes, 2015; Dwyer, 2010)[80].
2. The effectiveness of active learning has also been questioned (Prince, 2004).

[77] Which is good practice.
[78] These students have mostly come from a lecture-centric paradigm.
[79] It is difficult to distinguish between the comments on the pedagogy and the instructor.
[80] It is nice to know that systems engineering isn't the only discipline suffering from the perpetuation of myths.

***Table 17 Compliance Matrix***

| | Requirements | Lecture | Knowledge readings | Exercises | Individual assignment |
|---|---|---|---|---|---|
| 1 | Knowledge of subject domain | Poor | Best | In between | Repeated |
| 2 | Multiple solutions to a problem/ requirement | Listened | Experienced additional examples | Experienced | Not seen |
| 3 | Oral communications | - | Experienced | Experienced | - |
| 4 | Graphical/pictorial communications | Received | Experienced | Experienced | - |
| 5 | Ability to handle open-ended/ill-defined problems | - | Depends on external readings | Experienced | Depends on assignment |
| 6 | Holistic/Systems thinking | Listened | Went well beyond | Went beyond | Depends |
| 7 | Cognitive skills | - | 5 out of 6 levels in Bloom's taxonomy | Lowest 3 levels in Bloom's taxonomy | Depends |
| 8 | Teamwork | Some | Experienced | Experienced | No |
| 9 | Authentic Learning Environment | - | Experienced | Scenarios | - |

3. The effectiveness of trying to match the learning styles has been questioned (Pashler, et al., 2008). This may negate the need for further research to investigate how to implement Solution 3 discussed in Section 4.8.

The effectiveness of active learning and the relegation of the Dale Cone of Experience and the Learning Pyramid to myth status seem to be because there is no experimental data to validate the claims of more effective learning. Figure 4 (Mills, 1953) page 39) seems to have been ignored. Yet, after nearly 20 years of postgraduate classroom teaching in different modes and different countries, active learning in the authentic learning context still seems to provide more effective learning than passive learning as well as an enjoyable, informative and educational experience. Something is missing!

Instead of rejecting active learning because there is no experimental data, the systems approach is to take a different path and ask if there are any learning theories that support the improvement active learning seems to produce.

Perceptions from the *Generic* perspective indicate that there seems to be a similar situation in systems engineering. The MIL-STD 499 egg diagram (MIL-STD-499A, 1974) is a complicated representation of the Systems Engineering Process (SEP) which is itself an instance of the problem-solving process (IEEE Std 1220, 1998) Section 4.1). Trying to explain the egg diagram to students is difficult and trying to explain how the egg diagram maps into the SDP is even more difficult because some of the terminology means different things in different states of the SDP. For example, "requirements" specify what needs to be built and provide a:

- ***Solution*** at the end of the System Requirements state by specifying how the solution system will remedy the original problem.
- ***Problem*** at the start of the System Design State by specifying what needs to be built.

However, when comparing generic problem-solving process with the egg diagram, it seems that the egg diagram is described in solution or systems engineering implementation language while the generic problem-solving process is described using functions. It is much easier to explain systems engineering from the problem-solving perspective rather than the process perspective by first describing the generic problem-solving and then explaining how it is customised in each state of the SDP using the terminology appropriate to the state of the SDP.

Back to the scholarship of teaching and learning. Consider the learning process. The most widely used cognitive psychology information processing model of the brain based on the work of (Atkinson and Shiffrin, 1968) cited by (Lutz and Huitt, 2003) shown in Figure 24 likens the human mind to an information processing computer. Both ingest information, process it to change its form, store it, retrieve it, and generate responses to inputs (Woolfolk, 1998). Learning is …

still working on this section

The terminology used in describing types of active learning, as in Figure 5 describes scenarios. For example, "practise by doing" is one grouping of information storage and retrieval functions while reading is another grouping. In addition, the scenarios contain different number of repetitions for each low level learning function. If it can be shown that the location of the different activities in Figure 5 correlates with the number of retrievals then the figure would relate to how learning theory is applied in the classroom.

. Figure 5 contains the original activities in Dale's Cone and the Learning Pyramid, drawn as a horizontal Pareto chart and identifies the active and passive learning activities.

### 10.1 Research hypothesis

TBD

## 11 Further research

There are several avenues for further research. Specific avenues for further research include the following.

1. Correlating the components of the balanced classroom to learning functions as discussed in Section 10.1.
2. Converting a traditional experience-based class to the balanced classroom format is a non-trivial task. The problem of converting a degree program containing a set of stand-alone classes, a man-made system, into an integrated program is a complex problem and will require the program director to be an educational system systems engineer. Creating a generic process than can be applied across institutions is an even more complex problem worthy of further research since it will increase the effectiveness of teaching and learning systems engineering globally.
3. Focusing on the cognitive skills and measuring the degree of improvement in the creativity of the students. For example measurement techniques such as the Creative Engineering Design Assessment (CEDA) method (Charyton and Merrill, 2009) could be investigated and used to establish a baseline at

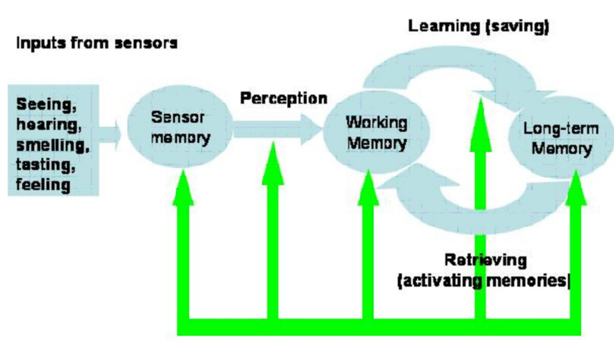


*Figure 24 Human Information System*

the start of the semester and then incorporated in the final examination to determine if an improvement has taken place.

4. Both the knowledge readings and the authentic exercises map into the scenarios in the Impresario model which "*calls centrally on student engagement and activity, and thus it is student-centered too. Still, the Impresario-teacher does not wait for students to take the initiative. She does not just facilitate the action on students' terms. Instead, the Impresario model is also teacher-centered, indeed profoundly and proactively, since well-chosen scenarios, ably and deftly staged, are essential to engage and structure students' action in the first place. Students' and teachers' activity is in characteristically different modalities, then, and both are profoundly active in this model. The "center" is neither primarily in the teacher nor primarily in the students, but is shared by all, albeit in different ways*" (Weston, 2015). Since the balanced classroom seems to be an instance of the Impresario model which combines teacher-centric and student-centric learning, it could form a platform for future research on effectiveness of the different learning models shown in Figure 5 (Weston, 2015).
5. Occasionally a weak team forms; defined as minimal expertise and experience in systems engineering. There needs to be a systemic and systematic way to detect this situation and transfer team members within two weeks of the class commencement.
6. Improving the assessment of team work. The current approach is to provide a team grade to all participants for the presentations and to grade individual parts of team documents. However, some of the team members do not believe that the grade will depend on their part of the document and poor sections produced by other members of the team will not lower their grades. These students spent time fixing up the document which wastes their time and provides a higher grade to some members of the team who don't deserve the higher grade. This is an undesirable situation and ways of adjusting the grade in accordance with individual contributions need to be developed such as in "Cooperative learning" defined as an approach to groupwork that minimizes the occurrence of those unpleasant situations and maximizes the learning and satisfaction that result from working on a high-performance team (Felder and Brent, 2007).
7. Should the approach to team formation be changed by separating the ice breaking exercise that demonstrates the effect of assumptions, vagueness in specifications and failure to comply with the requirements and from the selection of team members? Such a separation will permit the preselection of the team members by the instructor according to the recommendation in (Felder and Brent, 2007)?
8. Creating experiments or tests to verify:
    1) How the balanced classroom shapes up as a platform for cooperative learning (Felder and Brent, 2007) and how the elements of cooperative learning could improve the balanced classroom.
    2) If indeed the balanced classroom provides a better learning environment.
    3) The conditions in which the balanced classroom is an appropriate educational tool.

## 12 Summary

This paper discussed applying systems engineering to the problem of optimising postgraduate education. Although the research and development lasting from 1998 to 2015 covered both the content and the pedagogy, this paper:

- Focused only on the pedagogy.
- Suggested that instead of adopting a single technique such as the 'flipped classroom', a number of teaching techniques shall be used together as subsystems in an interde-

pendent manner blending them to enhance the learning experience.

- Described a balanced classroom which mixes a number of previously tested teaching and learning subsystems interdependently in a synergistic manner.
- Showed that delivery mode does not seem to make a difference.
- Concluded with a brief summary of the results of using the balanced classroom in three different classes in 2013 and 2014.

The contributions of the paper on the balanced classroom to the scholarship of teaching and learning are:

1. It is the first time that all the subsystems have been used (integrated) together interdependently as a system.
2. It overcomes the major defects in the "Flipped Classroom".
3. It maps into the Impresario model (Weston, 2015) as discussed in Section 11.
4. It provides examples of the use of different components and corresponding student reactions.

Section 2 introduced the context for the research. Section 5 provided some of the requirements for the balanced classroom developed during the research. Section 4 summarised some of the research and development leading up to the balanced classroom. Section 6 described the architecture and subsystems in the balanced classroom. Section 7 discussed the three parts of each session how the balanced classroom is used. Section 8 showed how the three types of content free knowledge are incorporated into the balanced classroom. Section 9 shared some of the results using the balanced classroom in three different classes in 2013 and 2014. Section 10 contained some reflections and comments, while Section 11 discussed possible avenues of future research.

## 13 Conclusions

The conclusions are, the balanced classroom:

1. Being "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" is truly an example of flipped learning (FLN, 2014).
2. Meets the requirements summarized in Section 5.
3. Is a fun teaching and learning experience.
4. Needs a teacher who understands the knowledge being taught. Instructors who teach the textbook by rote would not perform well in the balanced classroom.
5. May be used both in the traditional classroom and in online synchronous and asynchronous classrooms.
6. Is suitable for teaching postgraduate subjects other than systems engineering.

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