Introducing "knowledge readings": Systems engineering the pedagogy for effective learning

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Abstract. The literature on systems engineering education focuses on the nature of the knowledge to be taught, and tends to ignore pedagogical issues. This paper addresses that gap and begins with a discussion on the pedagogy of teaching systems engineering and ways to teach systems engineering in an effective manner. The paper then:

- Summarises the holistic approach to managing problems and solutions and defines the future conceptual feasible desirable situation (FCFDS) as an effective learning environment in classes on systems engineering and project management.
- Continues developing the FCFDS using systems engineering according to Arthur D. Hall (Hall, 1962) by perceiving the current situation from some of the holistic thinking perspectives on the perspective perimeter (Kasser, 2013) pages 90 - 110).
- Shows that by a slight modification to the current concept of operations (CONOPS) of a class in which the students provide the lecture rather than the instructor, the learning experience can be more effective, introducing the concept of 'knowledge readings'.
- Concludes with some observations and results from the use of knowledge readings over the last five years showing that knowledge readings:
    - Allow students to exercise cognitive skills at levels 3-6 of the upgraded version of Blooms' taxonomy shown in Figure 1 (Overbaugh and Schultz, 2013).
    - Provide a better learning experience, since learning for the purposes of presentation is a good way of ensuring retention of the knowledge.
    - Easily identify if students understand the knowledge being taught in the session.
    - Demonstrate that different people perceive information differently.
    - Enable the instructor to correct misinterpretations as they arise.
    - Provide students with the opportunity to practice presentation skills and obtain feedback on content and style.

Figure 1. Updated Bloom's taxonomy (Overbaugh and Schultz, 2013)

The major contribution of this paper is the use of systems engineering to combine the modified Bloom's taxonomy (Overbaugh and Schultz, 2013) with the often quoted learning pyramid developed in the 1960's at the National Training Laboratories, Bethel, Maine (Lowery, 2002), and the earlier Dale Cone of Experience[1] (Dale, 1954).

INTRODUCTION

The literature on systems engineering education and curriculum design (e.g. (Asbjornsen and Hamann, 2000; van Peppen and van der Ploeg, 2000; Sage, 2000; Brown and Scherer, 2000; Thissen, 1997; Jain and Verma, 2007)) focuses on the nature of the knowledge to be taught, and tends to ignore pedagogical issues. This paper:

- Focuses on the pedagogy and shows how systems engineering was used to increase the effectiveness of the learning experience.
- Discusses applying systems engineering to the problem of creating an effective learning environment in classes on systems engineering and project management using the holistic approach to managing problems and solution (Kasser, 2013) page 261) shown in Figure 2.

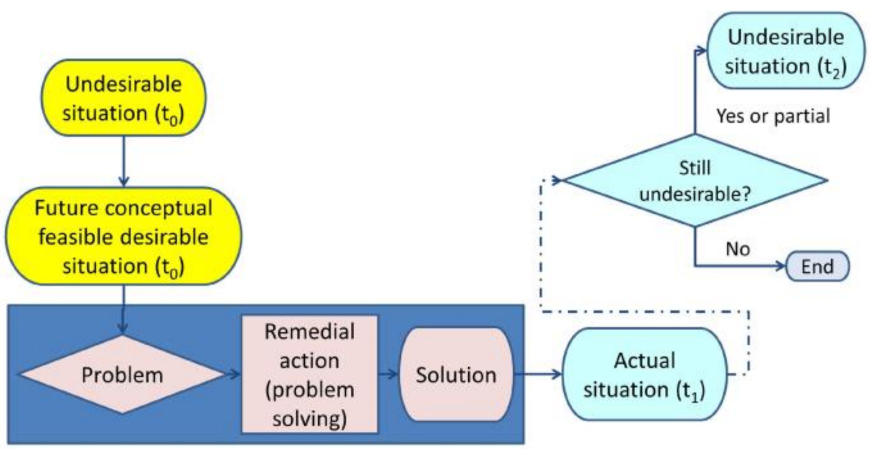

Figure 2. Holistic approach to managing problems and solutions

The undesirable situation is the need to create an effective learning environment in classes on systems engineering and project management.

The future conceptual feasible desirable situation (FCFDS) is an effective learning environment in classes on systems engineering and project management.

The problem is how to transition to the FCFDS from the current classroom.

The remedial action to achieve the transition is the solution system development process (SDP).

DEVELOPING THE FCFDS

The FCFDS is developed using the process shown in Figure 3 based on systems engineering according to Arthur D. Hall (Hall, 1962) where the hypothesis is the FCFDS. The process begins with the systems engineer making observations perceiving the situation from the eight descriptive holistic thinking perspectives on the perspectives perimeter (Kasser, 2013) pages 90 - 110). These perceptions may be seen directly or are the result of research into the problem, solution and implementation domains. Consider some of these perceptions.

[1] There are no numbers associated with Dale's cone.

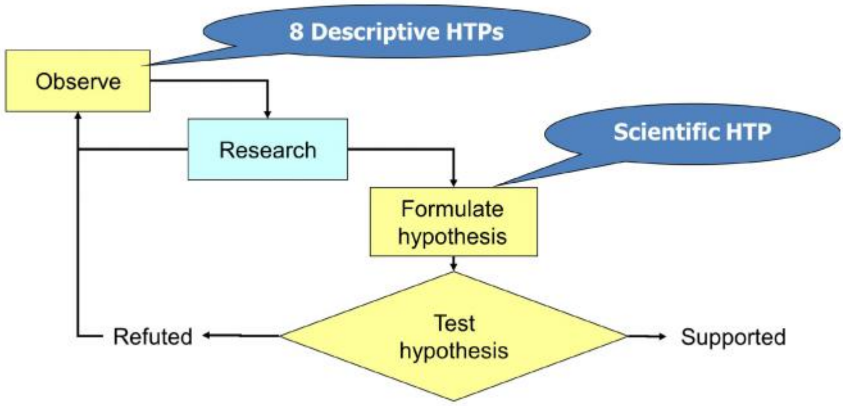

Figure 3. Holistic problem solving process

Big Picture Perspective

Perceptions from this 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.

Operational Perspective

From this perspective, in the traditional classroom the lecturer lectures, the students apply the knowledge in the exercises and report their results. The concept of operations (CONOPS) for a traditional class session[2] can be described in scenarios which include the following:

SC 1. The students read the session material individually before the session begins[3].
SC 2. A lecture by the instructor which summarises the readings, highlights the main points and adds additional material pertinent to the knowledge covered in the session.
SC 3. A group exercise which the students perform in their teams.
SC 4. A presentation of the outcomes of the exercise.
SC 5. A short discussion facilitated by the instructor.

Functional Perspective

"*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).

[2] This CONOPS applies to online classes as well as face-to-face ones in the classroom.
[3] 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 instructor will cover enough of it in the lecture.

The literature in the education domain indicates that 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.

Delivery Method

According to the often quoted learning pyramid developed in the 1960's at the National Training Laboratories, Bethel, Maine (Lowery, 2002), and the earlier Dale Cone of Experience[4] (Dale, 1954), which have been redrawn as Figure 4, listening to lectures is the worst way of learning while any of the forms of active learning is better. 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[5], perhaps for a week, finally presenting their solutions in competition at the end of the week.

Ideally, exercises need to be designed so when the students apply the knowledge to the problem posed in the exercise, they progress through the six levels of the upgraded version of Blooms' taxonomy shown in Figure 1 (Overbaugh and Schultz, 2013). However, the majority of exercises tend to only progress students to Level 3; application of the knowledge.

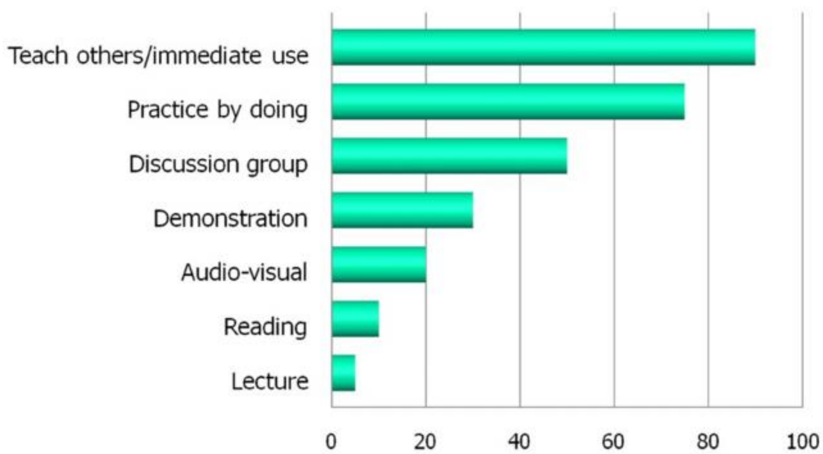

Figure 4. Claimed effectiveness of different learning techniques

Learning Styles

The literature on learning styles contains a number of different ways of expressing and evaluating learning styles including:

- **The VARK** (Visual, Aural/Auditory, Read/Write, and Kinesthetic) learning style instrument which divides learning styles in response to the input forms of 'visual', 'aural/auditory', 'read/write' and 'kinesthetic' forms (Fleming and Mills, 1992).
- **The Grasha-Reichmann** model developed in the early 1970s and used for more than two decades to identify the preferences learners have for interacting with peers and the instructors in classroom settings (Grasha, 1996) pages 127 and 128).
- **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 1.

[4] There are no numbers associated with Dale's cone.
[5] Identifying the knowledge and applying it to solve the problem

Table 1. 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

Optimising the learning experience by designing exercises to allow the students to progress through the five levels of the modified Bloom's taxonomy and match the individual learning styles of the students is a complex problem.

Quantitative Perspective

Perceptions from this perspective include the grading criteria which incorporate elements from an upgraded version of Blooms' taxonomy shown in Figure 1 (Overbaugh and Schultz, 2013) and four different ways of evaluating levels of critical thinking (Facione, 1990; Wolcott and Gray, 2003; Perry, 1981; Paul and Elder, 2006). Prior to using this approach, it was possible for students to gain high grades in a module by quoting the knowledge (Taxonomy Level 1) but without demonstrating a grasp of the application of the subject matter. When the assessments were changed from assessing the ability to quote the knowledge taught in a class to commenting and reflecting on the knowledge taught in the class, the grades fell into line with the student's in-class demonstrated cognitive abilities (Kasser, et al., 2005). Grades were assigned as shown in Table 2.

Table 2. Grading criteria

Grade	Understanding Demonstrated
A+	Student is able to reflect on what they have learnt and demonstrates the ability to generate novel, quality insights for the problems assigned. The student is able to conceptualise at a level extending beyond what has been covered in the module/session materials.
A/A-	Student has mastered a functional understanding of the knowledge derived from the module/session and substantial additional reading. Student demonstrates the ability to integrate the concepts presented and to uncover useful insights.
B+/B	Student demonstrates a clear understanding of how and when to apply the knowledge and can explain, analyse, and solve issues using the concepts presented in the module/session together with some external extensions from their own reading.
B-	Student is able to apply the content from the module/session within the conceptual framework presented. Work demonstrates a solid, procedural level of understanding of principles and practice.
C	Student knows the terminology and can apply the knowledge to solve a problem but the work is shallow, mechanistic and lacks insight.

SCIENTIFIC PERSPECTIVE: THE FCFDS

Operationally, the innovative FCFDS changes two of the current scenarios to introduce 'knowledge readings' which absolve the problem of designing exercises to allow the students to progress through the six levels of the modified Bloom's taxonomy shown in Figure 1 and match the individual learning styles of the students. 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 application of knowledge. The changes to the scenarios are:

- SC 1 can change from an individual reading to an individual reading followed by a group discussion session. Since students will be presenting the material in SC 2, they are now obliged to read and reflect on it before the session.
- SC 2 changes from a lecture by the instructor to a lecture by each student team called a "knowledge reading"[6]. The purpose of the knowledge readings presentations is to:

1. Provide a better learning experience (learning for the purposes of presentation is the best way of ensuring retention of the knowledge, see Figure 4). Students are supposed to demonstrate skills in all six taxonomy levels of ability when preparing for and presenting the knowledge reading in each session as described below.
2. Demonstrate that different people perceive information differently.
3. Enable the instructor to correct any misinterpretations as they arise.
4. Provide students with the opportunity to practice presentations skills and obtain feedback of content and style.

Requirements for the Knowledge Readings

The requirements for the knowledge readings have evolved[7] to the following:

1. Summarize content of 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 15 minutes.

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 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[8].

Consider each requirement:

[6] This solution evolved from requiring individual students to present a chapter from the text book in a postgraduate class on software Independent Verification and Validation (IV&V) at University of Maryland University College (UMUC) in 1997/1998 to requiring teams to present knowledge readings in postgraduate classes in systems engineering and project management at the National University of Singapore in 2009 - 2013.

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

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

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 (Taxonomy Levels 4 and 5) to identify and prioritize the main points.

3. Prepare a Brief on Two Main Points

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 (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 (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 holistic thinking (Kasser, 2013) to the content especially the Generic and Continuum holistic thinking perspectives. This is where the students can develop and apply their:
  - Ability to find differences among objects which seem to be similar,
  - Ability to find similarities among objects which seem to be different.

  The differences in the ‘ability to find …’ leads to the different type of persons shown in Table 3 (Gordon G. et al., 1974). For example, problem formulators score high in ability to find differences among objects which seem to be similar, and 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 Table 3) 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.

Both Gordon et al. and Gharajedaghi 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

Table 3. Factors conducive to innovation

Ability to find **similarities** among objects which seem to be **different**	HIGH	Problem solvers	Innovators
	LOW	Imitators/ Doers	Problem Formulators
		LOW	HIGH
		Ability to find **differences** among objects which seem to be **similar**	

The five types of systems engineers (Kasser, et al., 2009) may be mapped into Table 3, where:

- Type 5 = Innovators.
- Type 4 = Problem formulators.
- Type 3 = Problem solvers.
- Type II = Imitator/doers.
- Type I = Apprentices (not shown in Table).

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 (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 (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 15 minutes

This requirement puts an upper limit on the length of the entire presentation.

Grading in the FCFDS[9]

The correspondence between the updated Bloom's taxonomy levels, types of questions/instructions given to the students and how the ability is demonstrated in the knowledge readings, exercises and assignments in the FCFDS is shown in Table 4 adapted from Overbaugh and Schultz (Overbaugh and Schultz, 2013).

[9] The Quantitative perspective.

Table 4. 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

TESTING THE HYPOTHESIS: RESULTS IN THE CLASSROOM

The requirements have evolved as a result of experience in both the synchronous face-to-face and the online distance learning postgraduate classroom. Consider some of the results, first by requirement and then generically.

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[10].

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. Sometimes students try to brief the whole reading at this point demonstrating the inability to abstract the information[11].

[10] This generally happens at the beginning of the semester and improves as a result of experience.
[11] 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 (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.

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 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 (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 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 15 Minutes

This requirement also 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, the time limit was set to 5 minutes at the beginning of the session and the students were given 30 minutes to modify their presentation. This change received positive comments from a number of the students.

Other 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)[12]:
   - Multiple solutions to a problem/requirement.
   - Oral communications.
   - Graphical/pictorial communication.
2. Each class is different containing students with a different mixture of cognitive skills. The grading performed according the information in Table 4 tends to reflect the behaviour of the students observed in the knowledge and exercise presentations, and interaction in the question and response dialogues. For example, in one class with a mixture of cognitive skills high and low the grades were as shown in Figure 5. In another class where most of the students only demonstrated the remembering and understanding (Taxonomy Levels 1 and 2) levels the grades were as shown in Figure 6[13].

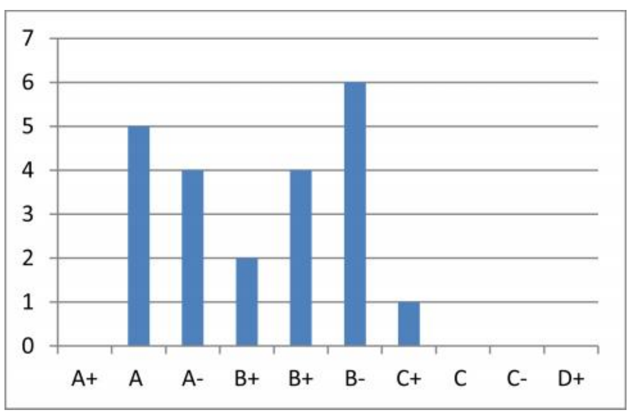

Figure 5. Class demonstrating split cognitive skills

[12] 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.

[13] The individual grades are made up from a combination of team work and an individual assignment. 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 have been told in several ways at different what content the assignment needs to cover. Thirty five out of the 42 students in the class also did not avail themselves of the opportunity to submit a draft of the final assignment for review prior to submitting the final version for grading.

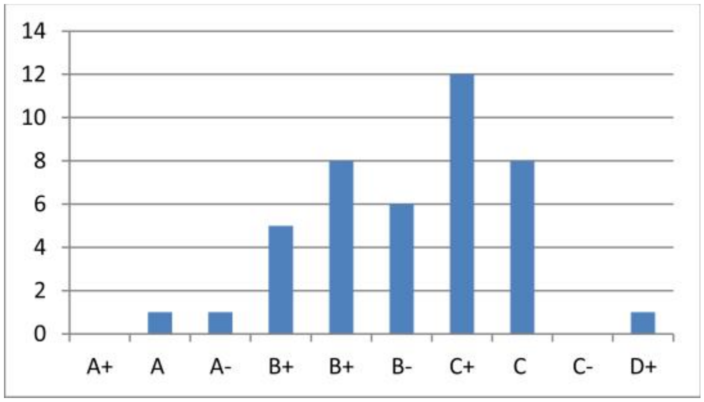

Figure 6. Class demonstrating mostly lowest level cognitive skills

3. Each team 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.
4. These presentations provide excellent 'learning opportunities' based on the mistakes the students in content, style and format.
5. 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 pointing 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[14].
6. Presentations evolve as the better techniques for presenting information get picked up by other teams. The instructor can point this out to the students showing that learning has taken place.
7. 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.
8. In spite of all the feedback, 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.
9. Students who are used to classes where they are lectured at, to need to be shown why the knowledge readings have been introduced. This is generally done in the introductory session to the semester.
10. 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.

SUMMARY

The paper began with a discussion on the pedagogy of teaching systems engineering and ways to teach systems engineering in an effective manner. The paper then summarised the holistic approach to managing problems and solutions and defined the FCFDS as an effective learning environment in classes on systems engineering and project management. The paper developed the FCFDS using systems engineering according to Arthur D. Hall (Hall, 1962) by perceiving the current situation from some of the holistic thinking perspectives on the perspective perimeter (Kasser, 2013) pages 90 - 110). The paper then showed that by a slight modification to the current CONOPS of a class in which the students provide the lecture rather than the instructor, introducing the concept of 'knowledge readings', the learning experience can be more effective. The paper concluded by sharing some results and

[14] Which is good practice.

perceptions from the use of knowledge readings over the last five years showing that knowledge readings:

- Allow students to exercise cognitive skills at levels 3-6 of the upgraded version of Blooms' taxonomy shown in Figure 1 (Overbaugh and Schultz, 2013).
- Provide a better learning experience since learning for the purposes of presentation is a good way of ensuring retention of the knowledge.
- Easily identify if students understand the knowledge being taught in the session.
- Demonstrate that different people perceive information differently.
- Enable the instructor to correct misinterpretations as they arise.
- Provide students with the opportunity to practice presentation skills and obtain feedback of content and style.

CONCLUSIONS

The FCFDS incorporating knowledge readings improves the learning experience. The knowledge reading presentations:

1. Allow students to exercise cognitive skills at levels 3-6 of the upgraded version of Blooms' taxonomy shown in Figure 1 (Overbaugh and Schultz, 2013).
2. Provide a better learning experience than prior classes without the knowledge readings.
3. Demonstrate to the students that different people perceive information differently.
4. Enable the instructor to correct any misinterpretations as they arise.
5. Provide students with the opportunity to practice presentations skills and obtain feedback of content and style.
6. Allow the students the freedom to learn the material via their own learning style. For example, those that prefer reading can read it, those that prefer hearing it can listen to the presentation, those prefer interaction can do so within their team and the full class discussion following the set of presentations in each session and those that prefer researching and self-seeking can do so.
7. 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).

The systems engineering approach to providing a better learning environment based on systems engineering according to Arthur D. Hall (Hall, 1962) combined the modified Bloom's taxonomy (Overbaugh and Schultz, 2013) with the often quoted learning pyramid developed in the 1960's at the National Training Laboratories, Bethel, Maine (Lowery, 2002), and the earlier Dale Cone of Experience (Dale, 1954). The result is an environment in which the students can demonstrate and improve their cognitive skills and critical thinking levels as well as learn about systems engineering and project management. Having enabled the identification of both student cognitive level and level of critical thinking, further research can now be performed on ways to help the students improve both their cognitive skills and levels of critical thinking.

BIOGRAPHY

Joseph Kasser has been a practicing systems engineer for 40+ years and an academic for about 14 years. He is a Fellow of the Institution of Engineering and Technology (IET), an INCOSE Fellow, the author of "*Holistic Thinking: Creating Innovative Solutions to Complex Problems*", "*A Framework for Understanding Systems Engineering*" and "*Applying Total Quality Management to Systems Engineering*" and many INCOSE symposia and other conference papers. He is a recipient of NASA's Manned Space Flight Awareness Award (Silver Snoopy) for quality and technical excellence for performing and directing systems engineering and other awards. He holds a Doctor of Science in Engineering Management from The George Washington University. He is a Certified Manager and holds a Certified Membership of the Association for Learning Technology. He also started and served as the inaugural president of INCOSE Australia and served as a Region VI Representative to the INCOSE Member Board. He has performed and directed systems engineering in the UK, USA, Israel and Australia. He gave up his positions as a Deputy Director and DSTO Associate Research Professor at the Systems Engineering and Evaluation Centre at the University of South Australia in early 2007 to move back to the UK to develop the world's first immersion course in systems engineering as a Leverhulme Visiting Professor at Cranfield University. He is currently a Visiting Associate Professor at the National University of Singapore.

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