New games for use in lectures to improve student learning

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Abstract - **Children learn a lot through playing games, probably because they become fully engaged and motivated and thus are more likely to practise. Moreover, game playing encourages experimentation and risk taking which are two key skills in independent learning. Consequently many authors have suggested that, where appropriate, introducing game playing into a more formal learning environment could improve learning. This paper introduces a novel game, developed by the author from a management context, which has been used successfully in lectures. The paper also gives some evaluation data on the game and reflections.**

Index Terms – Games, engagement, learning, fun.

1. INTRODUCTION

It is well known that several aspects help student learning [12]. Primarily the students need to be actively engaged [4,5,7,8] and this is facilitated by positive experiences, enjoyment, encouragement, a need to learn, practise, feedback and several other factors. However, a key factor is that students need to use the knowledge given to them, they must be active rather than passive. Another, perhaps less well expounded factor is that students benefit from opportunities to experiment or take risks, where they receive rapid feedback on this. In an iterative loop, experimentation with feedback encourages reflection and thus deeper understanding.

Unfortunately, the conventional university model of teaching is far more didactic with the lecturer as the holder of all knowledge. Their role is to transfer that knowledge into the students, without any corruption. This paradigm can treat the students as passive and gives no opportunity for criticism or reflection; the knowledge is not in debate. Consequently, although many generations of engineering students have coped with this approach, they are more likely to have negative memories of lectures and perhaps (like me) spent much of the time half asleep. Students learn little from attendance as they are too passive so even where many useful hints and examples are delivered, for most students their recall of these and recognition of the value could be small. Good teaching practise encourages lecturers to find mechanisms for increasing student alertness and participation as this will improve learning and recall. On similar lines, lectures notes and books can be rather dry and uninteresting and students often struggle to learn using just these resources.

The human brain has many other senses (touch, vision, emotion etc.) [1,11] and by engaging more of these, there is a better chance of engaging the student in deep learning. Hence, this paper focuses on the use of games as a means of improving student participation. Games, [3,9,10,13] can generate some excitement from the competition side and the natural embedding of teamwork encourages communication and thus debate and reflection, as well as gives opportunities to learn from each other; it even allows some risk taking. Ultimately, the students seem to enjoy participation, more senses are engaged and this will help with recall and generate a very immediate feedback on current understanding.

The difficulty for a lecturer is finding appropriate games that also reinforce the key learning outcomes. This paper presents one idea for a game that is easy for lecturers to adapt to their own topics. The 'model', adapted from a management game Elgood, [6] has been used in two different modules: (i) Mathematics and (ii) Classical control; and student feedback on the experience was collected. Thus this paper is able to report not only on the concepts, but also student perceptions of the process. It should be noted that the majority of the students were positive and during the corresponding lectures there was a very obvious buzz in the atmosphere.

The paper first gives some background to the context and the original management game [2]. Then section 3 discusses modification for an engineering context while section 4 presents the results of an evaluation study. The paper is completed with conclusions.

2. BACKGROUND

This section gives information on the degree programmes and level in which the games were used. It also gives details of the original source concept.

2.1 The teaching scenario

The author teaches courses related to systems engineering.

One of his courses, systems engineering mathematics is delivered in semester 1 of year 1. This is a key skills module taught to new students and hence also has to deal with transition issues as students adjust from school to university as well as a huge variability in the mathematical competence of the intake. The module covers a quick review of basic algebra and functions before introducing techniques such as trigonometry, calculus, solution of ODEs,

curve sketching and optimisation. Some of the biggest problems historically have been:

- Student weakness with core mathematical skills that are covered at school but have not been fully understood.
- Student disengagement. Students have not been fully convinced of the value of mathematics and hence have not been motivated enough to work hard.
- Students not fully aware of their own weaknesses until after the exam.

The department has adopted several strategies to tackle these issues. This paper considers just some aspects such as:

1. increasing student awareness of their own weaknesses.
2. encouraging peer assisted learning.
3. making lectures more fun and thus improving the potential for deep learning.

The use of a group based game in lectures encourages the majority of students to engage very actively[1]. Due to the time constraints and competitive side, students very quickly identify which problems they can and can't solve but moreover, work as a team on problems where they may be unsure thus learning from each other. Most critically, they become emotionally engaged and are highly active and thus increase the potential for remembering the lecture.

The second module discussed here is semester 1 of year 2 and covers topics from classical control, predominantly frequency response methods. For many students this is their only course in control and so they are not naturally predisposed to engaging, perhaps because they do not see it feeding into later studies. Consequently, albeit at a higher level, many of the issues are the same as for the mathematics module.

- Students often lack familiarity with, or enthusiasm for, the underpinning mathematics required for the module.
- Students see the module as an ordeal to be got through and forgotten.
- Again, students are not honest with themselves in testing their own progress or understanding and realise their own limitations only in the exam.

Once again, group based games can be used to tackle some of these issues using identical arguments to those for the year 1 module.

Remark: *It should be emphasised that the games are just part of the bigger picture of how the department manages student care and development. These cannot be interpreted as a solution on their own.*

2.2 Elgood management game - Find **T**

The basic game concept used was developed for management and is intended to help develop team working skills. The game is essentially very simple, but is performed as a race between several teams. The team which works most effectively, as a team, will invariably win. In this case team work starts from reading the rules and then dividing up tasks among the team members.

The game itself requires teams to find the value of **T**. To do this they need to answer and utilise the questions on a number of cards. All questions must be answered and moreover, in the correct sequence; teams need to discern what this sequence is. Thus a team must first sort out the correct sequence and then distribute cards between team members to ensure effective use of everyone's time. The scheme[2] is outlined in figure 1, where one can see that the procedure is summarised as:

1. Solve A1, use to solve B1, use to solve C1, …., use to solve H1
2. Solve A2, use to solve B2, use to solve C2, …., use to solve H2

   :   Etc

3. Use H1, H2, H3, … to solve for T.

The questions on the original game are mostly trivial such as: A1 = 120+234, B1 = A1/2, etc.

Remark: *The author's experience of playing the game with other academics is that they very quickly worked out the pattern and hence completed the challenge fairly quickly. However, this is certainly not the case with students who did not seem to realise the overall scheme for quite a while. However, the reader should note that encouraging effective team work is not a specific objective of this paper, even though an original context for the game.*

2.3 Using the value of T game in engineering lectures

The beauty of the find-T game is its simplicity. The basic concept requires the production of a small number (30-40) of numeric questions which build one upon another. This task to a large extent replicates what many lecturers would be doing anyway and thus is not a huge extra burden. The only real effort is to design some questions that fit into the general pattern and engage students with key learning from the module.

There is a mild overhead of designing questions with numbers that are simple enough to allow reliable or robust computation and thus based on simple rational numbers and fractions. Also, the task of printing questions onto suitably sized cards must not be underestimated. With 100 students, you would need about 25 packs of cards which means over 600 individual cards! For the trial, we produced the questions on power point and then printed, onto coloured card, six power point slides to a page. These then need cutting up.

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[1] There is also a secondary benefit of helping students get to know their peers without the awkwardness of social conversation.

[2] NOTE: This list is indicative and the precise number of cards and sequencing may be slightly different.

Remark: *If anyone would like the power point files containing these quizzes, please just email the author. Some typical questions are given in Tables I, II of appendix A.*

3. USE WITHIN ENGINEERING LECTURES

The find-T game was used on three occasions, at the beginning and end of semester for the mathematics module and in the first lecture given by the author (week 6) of the control engineering module. In both cases, the game was used for the 1st lecture the author had with the students. The hope was that, apart from being fun, it would engage many usually passive students and, in effect, force them to be far more honest with themselves about their current level of understanding and, in particular, expose worrying gaps that need work. There was also the potential for the lecturer to find out which topics caused greatest difficulty and this information can be used in planning lectures.

In order to better evaluate the efficacy of the games, students were asked to fill in some questionnaires. The remainder of this section gives an overview of the evaluation data collected, both from the lecturer and the students.

3.1 Evaluation by the lecturer

The lecturer was a key observer during all four sessions. In every case the same observations could be made:
- Students seem to be highly engaged and animated.
- There was clear evidence of team working and group discussion.
- Most students made a very obvious effort to complete the game and concentrated well for most of the lecture.
- A few students (2-3) disengaged from the activity and did not contribute actively to their group.

The atmosphere seemed positive and students seemed to enjoy the activity. The lecturer's main concern was that he may have made the games used to start off both modules a little too challenging, thus frustrating many average students who had a poor grasp of key topics. The games used at the end of the semester seemed to be tackled more competently, despite being much harder.

Summary: *For next year there is a need to look again at the existing quizzes and redesign some questions to be easier.*

3.2 Student evaluation of quizzes used in Systems Engineering mathematics

Students were asked to comment on their perception of the games in terms of appropriateness, usefulness, enjoyability, etc. and to add any verbal comments. The comments and quantitative data are given next.

Student comments on quiz used in 1st mathematics lecture in week 1.
- Showed me how much I forgot after the summer.
- Out of practice from the summer.
- Probably a bit much to begin with.

- A good mix of topics.
- Made me realise how much maths I had forgotten.
- Too easy
- Not just about maths but getting people to work in groups and get to know one another.
- Made me realise how little I know. Must study harder.
- Good chance to know what the module is about.

Student comments on quiz used at the end of semester 1
- It showed me how much I had learnt in the semester and which parts I need to focus on for the exam.
- Again, good range of topics.
- It's a good idea to make you …
- A good revision

Summary of quantitative data
Students were asked to choose which keywords they thought applied to the quizzes. The summaries for the early and late quiz are for the most part very similar.

- The majority (about two thirds) of students found the quiz fun, a good idea, helpful, refreshing and a good benchmark of their understanding.
- A sizable minority (about a third) found the quizzes too difficult and thus frustrating although many of these still thought it was a good idea and helpful. (Ironically a few said the game was too easy.)

In conclusion, the first year students enjoyed the quizzes and found them helpful. Thus, there is certainly ample evidence that this type of exercise is worth repeating with future students.

3.3 Student evaluation of quiz used in control engineering module

In the case of this module, the students completing the evaluation (those in attendance numbered about half the class) gave few substantive written comments on the quizzes used in these lectures. However, the majority did mark keywords and thus there is still some rich data to analyse. Indicative comments received are: (i) *Gave a good idea of my understanding and good team working/building exercise and (ii) helped to reinforce material required for assessment.*

In this case, the quantitative data on keywords has been summarized in table III of appendix B. As with the 1st year module, the majority thought it was a good idea, a good benchmark of understanding, a refreshing change, helpful and a reasonable majority thought it was fun. A minority found it frustrating or too difficult but often covered this by saying nevertheless it was helpful and a good idea.

3.4 Staff reflections and an alternative game

It has become apparent that a major problem with the find-T game, as posed in Tables I, II and figure 1, is:

- that it relies on students solving problem A1 before they can move onto to B1, and this is a major restriction in many cases. What if they cannot solve A1?
- It does not give intermediate marks. You either find-T or don't.

In the management context the questions were easy and the game was encouraging effective teamwork. Here we found that it was difficult for the students to complete the game in 40 minutes, even though each student should only need to solve 6-7 relatively straightforward problems.

The quiz exposed weaknesses very well but the game structure, as set, assumes that the groups will be able to answer everything whereas in reality, even an entire group may not be able to answer all the questions. Consequently, lecturers need a mechanism to allow progress where groups cannot answer some questions and also to overcome potential disenchantment of the weakest students.

Consequently, after some reflection, the author decided to trial a new template, where better progress could be made and also student progress could be assessed or contrasted on a finer scale. This would also help with the competitive element more. Ironically, this template was very close to a more conventional quiz model, whereby each question has a distinct and independent answer. This reduces the team work component to some extent although teams would still need to divide up the questions amongst the members. However, it is notable that the later quiz (used for the control engineering module at the end of semester) received more universally positive comments than the first. This data is summarized in Table IV of appendix B.

Reflections on this would suggest that the better feedback was probably because of two main reasons:
- All questions could be tackled independently leading to less frustration with progress.
- Students were at the end of the module and felt comfortable with the content of the quiz.
- The first quiz, being at the start, covered pre-requisites that many had forgotten and, being used in lecture 1, came as a shock.

4. CONCLUSIONS

The author has experimented with introducing games into lectures for year 1 and 2 modules. In both cases, the lecturer's own observations were that the students were highly active and engaged, and this alone will improve learning substantially. Some basic evaluation data given by the students gives further strong evidence that the student's themselves found the exercise useful. The challenge for the author is to consider where minor adaptations to the game format selected may facilitate even better engagement, especially for those students who became frustrated.

In the longer term, the author also intends to consider the wider issue of game design within a lecturer environment to encourage more learning. The games described in this paper help students assess their level of understanding and encourage some community building through team work and competition. However, although there is a small potential for peer learning and discussion, the timescales were such that this probably happened only to a minimal level. Thus, no new material was presented and generally one would want the game to introduce new material as well as reinforce existing knowledge.

Current plans are to look at making each stream (see figure 1) focus on just one topic rather than having all topics in each stream. This way, failure to understand one topic will cause failure only on a single stream. Also, one could gradually increase difficulty as one moves up the stream, thus giving finer feedback on student understanding. Other under explored alternatives could reflect typical game show formats such as University challenge; the first team to answer each question gets the marks.

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APPENDIX A: TYPICAL QUESTIONS GIVEN IN THE FIND-T QUIZZES

TABLE I
SYSTEMS ENGINEERING METHODS

CARD	QUESTION	ANSWER
B5	$(7/5)A5x-C5$	$21x$
A5	Hypotenuse with sides 9 and 12	sqrt(225)=15
C5	Min root of $(2x^3+6x^2+4x)$	0
F5	$\log[\mathrm{Sin}(D5\pi/4)]+3[E5^6/E5^4]/4$	12
D5	Max. root of $(2x^2-6x+4)$	2
E5	$[3^4 2^6 4^2 9^{-1} 4^{-4}]/9$	4
P5	$\cos(B5)-F5/2$	$\cos(21x)$ -6

TABLE II
FREQUENCY RESPONSE METHODS

CARD/QUESTION	ANSWER	
B5=A5*C5	28arg(60)	
A5	7arg(40)	
C5	4arg(20)	
F5= D5-E5	1-5i	
D5	7-2i	
E5	(6+3i)	
P5 = $[B5/7]^3/(F5+4i)^2$	$[4arg(60)]^3/[1-5i+4i]^2$	32arg(270)
R = $P1^2 P2 P3 P4/P5$	(16.16.3.2)/(32sqrt(2))arg (30+120+180-150-270)	24sqrt(2) arg(-90)

APPENDIX B: STUDENT EVALUATION DATA ON QUIZZES

TABLE III
NUMBER OF TIMES WORD MARKED FOR GAME IN FREQUENCY RESPONSE METHODS

Fun	ok	boring	helpful	Too difficult	Difficulty about right
21	25	3	20	11	11
Frustrating	Refreshing change	Good idea	unhelpful	Good benchmark of understanding	Better later
11	22	35	4	21	11

TABLE IV
NUMBER OF TIMES WORD MARKED FOR 2ND QUIZ IN FREQUENCY RESPONSE METHODS

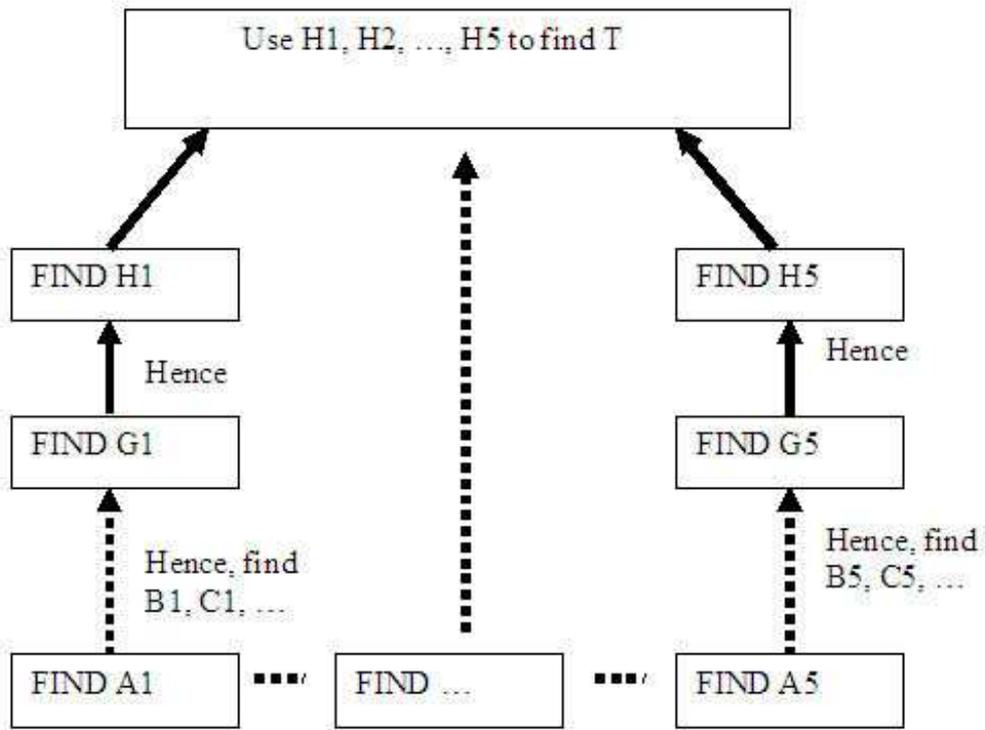| Fun	ok	boring	helpful	Too difficult	Difficulty about right
25	21	2	39	3	18
Frustrating	Refreshing change	Good idea	unhelpful	Good benchmark of understanding	Better later
5	27	41	2	38	4

FIGURE 1:
FLOW DIAGRAM GIVING ILLUSTRATIVE CONCEPT OF FIND T GAME