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Two different kinds of practicals in a vibrations class

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Abstract: Two very different styles of practicals have been introduced into a conventional engineering vibrations course. This was a reintroduction of practical work into a class where it had been deleted for resource reasons. The first of the reinstated practicals demonstrated rotating out of balance and with it the use of common instrumentation such as FFT analysers. It was a conventional style of practical. The second demonstrated modal frequencies and modeshapes for a multiple degree of freedom system using innovative simple experimental equipment that required extensive hands-on activities from the students. In this second practical the students explored the phenomena for themselves. Surveys of students revealed that they saw value in both styles of activity. Further, they would not as a group have preferred more lecture or tutorial time instead, or even private study time. This paper describes the aims of including experiments again in the course, how the practical activities were constructed, and how the practical periods were organised. It also explains how the activities were assessed and gives full details of the student reactions.

Keywords: Engineering mechanics, vibrations, practicals, cost-effectiveness

INTRODUCTION

Practicals – or laboratory work – add a different dimension to what would otherwise be a straight lecture/tutorial program. Our aim in this project has been to re-introduce practical work into a course in which the previous laboratory component had lapsed.

However, laboratory activities require resources of staff and student time that could be used in other ways to improve the learning environment for students. For example, it might be better to have additional tutorial time rather than require students to undertake a practical task. One objective of this project has been to find out from students whether they feel that practical work is the best use of their time. In addition, practicals require equipment that may be expensive (such as FFT analysers), and the design and manufacture of experimental rigs, and it is important to assess whether these costs are warranted.

Laboratory work can take various forms, such as (Aglan and Ali, 1996, Barnard, 1985, Butterfield, 1997, Edward, 1997, Eley *et al*, 1995):

- simulations;
- demonstrations;
- experiments with formal laboratory equipment, instrumentation and specific instructions – these often also demonstrate the use of instrumentation;
- hands-on experiments that require students to explore for themselves, based on general guidelines.

In this project, two practicals of very different style have been implemented and students surveyed to see whether they prefer one or the other or perhaps see value in both. The first practical involved a classical style of experiment, adapted from elsewhere, that introduced formal instrumentation as well as a simple vibrating element. Instructions were clear and precise. This allowed direct comparison of theory and experiment. The second practical was designed to be much more interactive, with students getting their hands directly on the equipment and being able to feel the phenomena they were investigating. Although comparison with theory was a vital part of the scheme, the instructions were intentionally left open to allow space for imagination.

The experiments have been conducted twice in successive years, with improvements made between implementations.

This project had four objectives.

1. To reintroduce a laboratory component – justified on the intuitive assessment that it would be a good addition to the learning environment.
2. To find out students' evaluation of whether practicals were a valuable use of time, or whether they would prefer to use the time in other ways.
3. To find out student reactions to the two different styles of practicals
4. To evaluate the whole program and make recommendations for subsequent years.

IMPLEMENTING THE PRACTICALS

Practical 1

The objectives of this practical were to (i) demonstrate free and forced vibration of a single-degree-of-freedom (single-DOF) spring-mass-damper system, (ii) expose students to typical instrumentation used in vibration measurements and analysis, and (iii) improve the students' report writing skills and thereby their written communication skills.

In the experiment a disk was driven by a small motor that was mounted on a metal beam. An eccentric mass at the outer periphery on the disc provided out of balance excitation that varied in frequency as the speed of the motor was varied. An accelerometer was placed on the beam. A spectrum analyser enabled both the time history and frequency spectrum to be observed. A schematic of the rig and instrumentation is shown in Figure 1.

In the first part of the practical the beam was initially displaced (by physical plucking) and the time history was recorded. Using an FFT analyser, the frequency spectrum was observed. From this first part, the damping in the system and the natural frequency were obtained. A power supply was then used to drive the motor so that the beam oscillated in transverse displacement due to the rotating out of balance mass. The students were instructed to drive the motor at several speeds below and above the resonance frequency, and plot the response as a function of frequency.

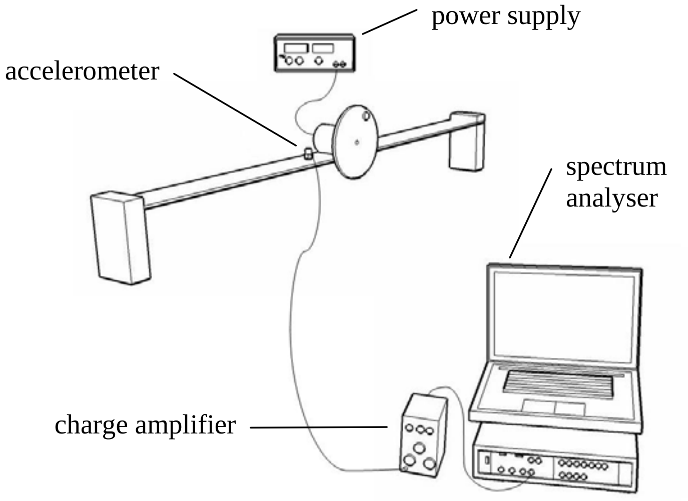

Figure 1. Schematic of the single-DOF experiment and instrumentation.

To demonstrate basic concepts of single-DOF vibration, the classical experiment was demonstrated to students in groups of 10, in a one-hour period. To accommodate a class of about 200 students in a one-week period, four identical rigs were made and additional periods allocated in addition to the usual tutorial and lecture periods for that week. The practical was demonstrated to parallel groups in a one-week period in order to ease the complex problem of timetabling, and facilitate the assessment process. This was worth the additional costs, which were mainly for the instrumentation required for each rig (accelerometer, charge conditioning amplifier, FFT analyser and power supply). Students booked their own time using an on-line booking system. Each experiment was demonstrated by a member of staff or a tutor. Student interaction was strongly recommended by the lecturer in charge and encouraged by some demonstrators (although many students in fact played a passive role).

For the practical write-up, students were required to compare the predicted and measured results of the free and forced responses of the single-DOF rotating out-of-balance system. Students were instructed to write up the practical as a formal report, using the headings Aims, Introduction, Theory, Experiment, Discussion and Conclusions, and others where appropriate. The students were required to type up their report using equation editor and tables. They were also reminded that proper use of grammar would be expected.

Practical 2

The objective of this experiment was to provide a learning experience based on intimate, physical, hands-on involvement with a multi-DF system, and to get students to reflect upon their learning.

To demonstrate basic concepts of multi-DOF vibration, a simple but novel experiment was devised that provided a rotational representation of a three-DOF system. As shown in the upper schematic in Figure 2, it is a rotational three-DOF version of the classical trifilar vibration system. Three plywood disks of diameter 160mm were each suspended in sequence by three filaments of fishing line. A central wire (not shown in the figure) kept the disks aligned. Each of these table-top rigs stands 600mm tall. By giving the disks appropriate initial rotary displacements and letting go simultaneously it is possible to excite each of the three torsional natural modes of vibration, or a combination of them all.

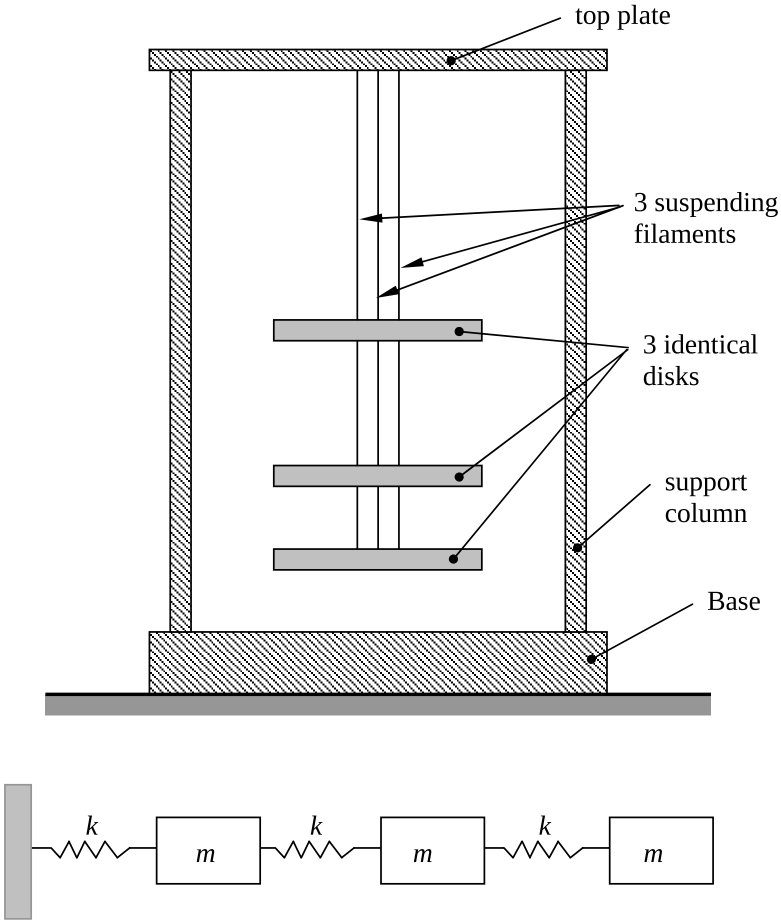

Figure 2. Schematics of the rotational three-DOF experiment (upper) and equivalent linear model (lower).

Through careful choice of parameters, the modeshapes for this rotational configuration were made the same as those of a linear equivalent with three equal masses and three equal springs, as shown in the lower schematic in Figure 2. This experimental rig had been trialled the previous year and was revised for the second year of operation in order to make the natural frequencies of vibration lower (and hence slower), thereby making the modes of vibration more easily observable.

This vibration experiment was initially devised, developed, implemented and reviewed as part of a final year undergraduate project (Kidson, 2004). It was devised with reference to Kolb's learning cycle (Kolb, 1984).

As with the single DOF experiment, multiple copies of the rig were made so that a class of 200 students could complete the experimental program in just over a week, with students booking a laboratory time using the on-line booking system.

In their half hour laboratory period, students worked in small groups: 3 to 6 students per group in year 1 and 5 students per group in year 2. The students excited the three-DOF systems by hand in an attempt to generate motion in each of the three modes of vibration. They had to work out for themselves how to arrange the initial displacements and how to release the disks simultaneously. The modeshapes were to have been calculated beforehand by the students in an assignment that preceded the laboratory period, but in case no one in the group had managed to calculate them correctly, data were provided on the day. Students were instructed to compare the predicted and measured ratios of modal frequencies and asked to see what they could learn in general about multiple-DOF systems.

Students worked on their own in teams, but with tutors available to guide them. Several groups took to heart the suggestion that they explore what could be learnt from these new experiments and found novel ways to excite the modes, for example by rotating the whole rig at the relevant natural frequency.

The report for this practical aimed to encourage the students to reflect on what they had done, using theory to explain what they had seen and understood. They were then to say how much success they had in getting the specified data, evaluate this whole practical as a learning experience, and reflect on an applications of multi-DOF in everyday life.

SURVEYS OF PRACTICALS

General scheme for surveys

Questions in the surveys fell into three categories:

1. Whether students thought that practicals in general were a good use of their study time.
2. What students thought about each particular practical.
3. How students responded to the contrasting styles of the two practicals.

Students were surveyed after practical 1 (165 responses) and again, using a different survey questionnaire, after practical 2 (78 responses). The questionnaires are shown in the Appendix.

Survey for practical 1

As shown in the first survey questionnaire (Appendix), after practical 1 students were asked about:

1. how they would prefer to use their time allocation for this course, both class contact and private study;
2. what they thought about the value of this practical.

Survey for practical 2

As shown in the second survey questionnaire (Appendix), after practical 2 students were asked:

1. what they thought about the value of this practical;
2. which of the practicals they preferred (if they had a preference), and why.

Results of surveys

Were practicals in general a good use of time?

When students (165) were asked whether they would like more or less of the following teaching and learning activities, they responded as in Table 1.

Table 1. Student preferences for time spent on teaching/learning activities

	More (%)	Less (%)	Same (%)
Lectures	8	29	63
Tutorials	35	8	57
Practicals	30	13	57

Student assessment of the value of practical 1 (single-DOF rotating out-of-balance experiment)

When asked about the value of practical 1, 165 students responded as in Table 2.

Table 2 Student assessment of practical 1

Good use of time	95% (Yes)
More lecture time instead	92% (No)
More tutorial time instead	71% (No)
More private study time instead	72% (No)

Written feedback comments included:

- Good practical, understood the difference between the undamped and damped natural frequency of a single-DOF system
- Adds value to the course
- More damping in the system useful
- More complex practical would be beneficial
- Does not extend knowledge
- Too easy/not learnt anything new
- Tutorials instead would be helpful
- Would like more time for general consultation instead

Student assessment of the value of practical 2 (three-DOF trifilar experiment)

When asked about the value of practical 2, 78 students responded as in Table 3.

Table 3 Student assessment of practical 2

Practical: Good use of time	92 % (Yes)
More lecture time instead	75% (No)
More tutorial time instead	75% (No)
More private study time instead	81% (No)

Written feedback comments included:

- Able to see what was learnt in the class/Clarified a lot of theory/Makes understanding easier
- Too simple, but idea is good
- Interesting and simple/Good, simple practical to understand the concepts
- Not a lot of work but learnt a lot/Good use of 30 minutes

- Very useful/Fantastic practical/Good experiment
- Better equipment would be good/Extend the practical
- Demonstrated the concepts in a clear simple form
- Could be a demonstration in a tutorial class.

Comparative value of the two practicals

Student responses (78) to questions comparing the two practicals are given in Table 4 below.

Table 4 Comparisons of the two experiments

Noticed a difference in style between the two practicals:	96% (Yes)
Preferred Practical 1 (single-DOF practical)	17%
Preferred Practical 2 (three-DOF practical)	44%
No preference	40%

Student comments included:

- Both [practicals] were interesting in their own right
- Both [practicals] worked well in demonstrating concepts
- Both [practicals] were different yet valuable experience
- Instrumentation in practical 1 but none in practical 2
- Practical 2 better for understanding
- Simplicity in Practical 2
- Liked the less formal style of Practical 2; but report hard to write
- More hands on practicals like Practical 2
- No hands on in Practical 1 (Note: This was not the intention. Students were meant to have a hands-on contribution, but some demonstrators were too controlling.)
- Had complete control on Practical 2; but Practical 1 was observed

DISCUSSION

In the short time that students had to think about use of their in-class learning time, most concluded that it was about right as it was, that is:

Conventional lectures:	2 hours per week
Conventional tutorials:	1 hour per week, including practicals
Practicals:	2 hours in total

However, there was a substantial minority who would prefer fewer lectures (28%), more tutorials (35%), or more practicals (30%). Almost all students found the practicals to be a good use of time (over 90% for each), and most did not want more lectures, tutorials or private study instead.

From the comparison of the two practicals, the students nearly all (over 95%) did recognise the difference in style. 40% had no preference and of those who did express a preference more preferred the hands-on style of practical 2. Reasons for these are given in the written comments.

In its first year of implementation, practical 2 was developed, implemented and reviewed as part of a final year thesis project investigating engineering education for mechanics courses (Kidson, 2004). Practical 1 is currently being further developed, again as an undergraduate final year thesis project, to demonstrate the principles of vibration control using a dynamic vibration absorber (Oon, 2006). In this case, the absorber is a single-DOF spring-mass system that has been designed, constructed and implemented to reduce the transverse displacement of the beam at the resonance frequency of the original system. This mechanism of vibration control will be included in practical 1 in future laboratory activities.

CONCLUSIONS

Two very different styles of practicals have been reintroduced into a core 3rd year course in mechanical engineering vibrations.

Students saw value in both styles of activity. Their feedback strongly indicated that they found the hands-on experience with experimental rigs, and exposure to instrumentation used in vibration measurement and analysis, to be effective in reinforcing their understanding of the course material. The majority felt that these practicals added more value to their vibrations course than the alternative of having more lecture/tutorial time or even private study time.

The writers believe too that the practicals added value to the students' engineering education, not only for the reasons given by students but also because they provided opportunities for students to develop their written communication skills.

Students and staff agree that reintroducing practicals in this way into this engineering vibrations course has been a very positive step.

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APPENDIX SURVEY DOCUMENTS

SURVEY OF TIME ALLOCATION AND REACTIONS TO EXPERIMENT
IN MECH3330 VIBRATION ANALYSIS, S2 2005
prepared by R Ford and S Kanapathipillai, 14 September 2005

You have just completed a practical in MECH3330. It took up student and staff time and we want to know if this was the best way to use it. We have two questions:

1. In your general experience, is the time taken by practicals in your various courses justified by the learning they help you achieve
2. Was this particular practical in MECH3330 effective in helping you learn

To answer these, there are two sets of questions below concerning:

1. how would prefer to use your learning time in MECH3330
2. your assessment of the usefulness of the practical you have just undertaken in this course

Set 1   Use of student study time in MECH3330

activity	**our current estimate**	**your preference (more or less)**
class contact		
lectures	26	
tutorials	12	
practicals (prac 1 and prac 2)	2	
in-session tests	2	
final exam	3	
private study		
review notes/textbook	4-8	
do tutorial problems	12-20	
do assignments (2)	6-7	
write up practicals	8-10	
TOTAL	75-90 hours	this is the UNSW specification

comments…………………………………………………………………………………………

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Set 2   Value of this practical in MECH3330 in Session 2 2005

Value of this practical   (Beam with electric motor)

1	Was this practical a good use of time?	Yes/No	
2	Would you rather have had more lecture time instead?	Yes/No	
3	Would you rather have had more tutorial time instead?	Yes/No	
4	Would you rather have had more private study time instead?	Yes/No	

Please add comments overleaf on the value of this practical and how it could be improved.

SURVEY OF REACTIONS TO EXPERIMENTS (part 2)
IN MECH3330 VIBRATION ANALYSIS, S2 2005
prepared by R Ford and S Kanapathipillai, 20 October 2005

You have just completed your second practical in MECH3330. It took up student and staff time and we want to know if this was the best way to use it. We have two questions:

1. How useful was the practical you have just undertaken in this course (practical 2)?
2. What was the relative value of the practical you have just completed (practical 2) compared with the first practical you undertook (practical 1)?

Set 1 Value of this practical (three-degree-of-freedom system) in MECH3330 in Session 2 2005

1	Was this practical a good use of time?	Yes/No	
2	Would you rather have had more lecture time instead?	Yes/No	
3	Would you rather have had more tutorial time instead?	Yes/No	
4	Would you rather have had more private study time instead?	Yes/No	

comments…………………………………………………………………………………
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Set 2 Comparative value of the two practicals in MECH3330 in Session 2 2005

Practical 1 (rotating out of balance) and Practical 2 (three-degree-of-freedom) were designed to be different, eg in degree of involvement and style of equipment

1	Did you notice a difference in style between the two practicals?	Yes/No	
2	Did you prefer practical 1 or practical 2 or were they equal?	1/2/equal	

comments…………………………………………………………………………………
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Please add overleaf any extra comments on the value of practicals and how they could be improved.