Using Lecture Demonstrations and On-line Discussion Groups to Enhance Learning in a Photonics and Fibre Optics Unit

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ABSTRACT

A second year Photonics and Fibre Optics unit in our B.Sc. (Photonics) course at Swinburne University is delivered via power-point lectures, problem-solving tutorials and laboratory sessions. Student interest and participation in lectures is enhanced by the use of "interactive learning" methods such as "live" lecture demonstrations, "virtual demonstration" video clips, computer simulations and on-line discussion groups. Hands-on lecture demonstrations add variety and excitement to lectures, and if used as part of the "predict, observe, explain" sequence can illicit student interaction, critical thinking and peer dialog. Lecture demonstrations are also used to introduce or reinforce particular "key concepts", which assists comprehension for many students. Video clips are used to show lecture demonstrations that are too difficult to set up in a normal lecture. Similarly, interactive ray-tracing simulations greatly extend what can be taught with words and diagrams alone. Finally the cooperative learning style (developed in tutorial sessions) can be extended with properly structured (and assessed) on-line discussion groups, in which all students are expected to participate.

Keywords: Photonics, fibre optics, lecture demonstration, video clips, interactive learning

1. INTRODUCTION

The discipline of photonics is underpinning the enormous expansion in communications bandwidth that has made a practical Internet possible. As such, it is the enabling technology for this rapidly expanding information network. In addition, photonics is also playing a major role in a wide range of new, high technology areas in manufacturing, entertainment, defence and medicine. Despite the current global down-turn in high technology industries, it would appear that the long-term fundamental indicators for photonics are very sound. There is an expectation that the photonics industry will continue to grow strongly world-wide and that a severe shortage of photonics graduates will exist. A recently commissioned industry report has predicted that there will be a need for over 20,000 new photonics employees in Australia over the next decade if it is to maintain its current market share in the global photonics economy. Fig. 1 (taken from a recent article by Sceats and Elenius[1]) shows that, in Australia alone, there is a projected need for around 600 new tertiary-trained photonics engineers and scientists each year for the next decade.

To help meet this projected demand, several universities in Australia have decided to develop photonics-related science and engineering courses. Swinburne University of Technology has recently established a significant strategic initiative in photonics research called the Swinburne Optronics and Laser Laboratories (SOLL)[2]. SOLL has over 20 researchers (academics and postdoctoral fellows) that would be qualified to teach into a photonics-related undergraduate degree program. At Swinburne we have developed a three-year Bachelor of Science (Photonics) program with an additional sandwich year of industry-based learning (that is optional but highly recommended). We also have developed a five-year Bachelor of Science (Photonics) / Bachelor of Engineering (Telecommunications and Internet Technology) double degree program (again with an additional, optional, industry-based learning year). These courses now have been accredited and will be offered for the first time in 2002.

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Some of the distinguishing features of these programs include the following:
(a) Vertical integration of core subjects (with photonics and telecommunications units appearing in every academic year of the programs).
(b) A common entry point and common syllabus for the first two foundation years (so students do not have to make a final decision on whether to choose the single or double degree option until the end of second year).
(c) Optional industry-based learning year with a photonics-related industry partner (occurs at the end of the second academic year).
(d) Both programs are a direct entry point for the existing one-year Swinburne Bachelor of Science Honours program (in either Biophotonics or Optronics & Lasers). More details of all three photonics programs can be found at the Swinburne photonics web site[3].

2. PHOTONICS AND FIBRE OPTICS UNIT

Although the photonics programs at Swinburne University are a relatively new initiative, a (second year level) photonics and fibre optics unit has existed at the University for many years. This one-semester unit (which forms 25% of a normal semester workload) is an elective for several undergraduate science and engineering programs. It has an intake of approximately 90 students each year. The students taking this unit have a wide variety of backgrounds with majors ranging from electrical engineering to medical biophysics and it is a challenge to deliver a stand-alone course that is both instructive and interesting to such a diverse cohort of students. The unit consists of 36 hrs of formal lectures, 6 hrs of tutorials and 10 hours (5 x 2hr sessions) of laboratory work. In the past, students also prepared a semester-long, web-based team assignment. As it was felt that the assignment did not significantly contribute to students' understanding in the unit, this activity was replaced in 2001 by a pilot program of student participation in on-line discussion forums. Lecture material is assessed by end of semester exam. Tutorials operate in a cooperative learning mode where students work together in groups to solve numeric-type problems, and students receive a participation mark towards their final grade for attending tutorials. Laboratory work is done in pairs, and is assessed by supervised computer-managed learning (CML) tests[4] for each laboratory experiment and one written minor report for one (randomly-chosen) laboratory experiment. The web-based assignment (or more recently the on-line discussion contribution) is also assessed and contributes to the students' final grade in the unit. Full details (syllabus, assessment etc.) for this unit can be found at the Photonics & Fibre Optics Unit web site[5].

Despite the diverse nature of the cohort of students undertaking the photonics and fibre optics unit, it performs very well in annual university-run subject evaluation questionnaires. In 2001, just under 90% of the students who responded to the survey agreed or strongly agreed that the unit was well presented, and a similar percentage agreed or strongly agreed that they were satisfied with the quality of the teaching. Similar results have been obtained in subject evaluations for previous years. Progression rates in this unit are also very encouraging with 85% of students passing in 2001, with similar pass rates in previous years. So how can a photonics unit perform well with such a varied group of science and engineering students? One of the main contributing factors is the use of strategies that help motivate students and engage them in the learning process.

The lecture material for this unit is delivered as face-to-face lectures using Microsoft power-point presentations. At the end of each lecture, students are given access to the electronic version of the presentation, so that the material can be revised, annotated and/or printed. As students no longer need to copy down notes in class, there is much more time for other more interesting things... like *real* photonics research examples, lecture demonstrations, video clips, simulations and so on. Many of these activities can be used to engage students actively in discussions and critical thinking about the issues being covered in the lecture. There is now considerable evidence to suggest that interactive engagement strategies can greatly enhance students' conceptual understanding in many science- and engineering-based courses[6,7,8]. The discussion of issues not specifically covered in lectures but still of general interest to students in a photonics course can also be encouraged, especially in the on-line discussion forums.

In the 2001 student survey, of those students who specifically wrote comments on what they thought was the one "best aspect of the subject", 55% chose the power-point lecture style, 20% chose the lecture demonstration activities, 7% chose tutorials, 7% chose lab work and 7% chose the on-line discussion forums (even though this particular pilot program ran for only 4 weeks in the semester).

3. LECTURE DEMONSTRATIONS

It is well known that lecture demonstrations can provide a kinetic, visual extension to traditional “chalk and talk” (or in this case “click and talk”) lectures. This added perspective enhances interaction and comprehension for a large proportion of students who tend to use many different learning styles. Swinburne University has produced a set of portable lecture demonstrations and video clips (called “Physics in a Suitcase”) that are suitable for introductory physics classes[9,10]. One of the “Physics in a Suitcase” kits (Light and Optics) has been expanded to include additional demonstrations that are used in the photonics and fibre optics unit, and for photonics promotional & outreach programs in secondary schools[11]. A few of these lecture demonstrations are outlined in the following paragraphs.

Lecture demonstrations are a great way of getting students involved and thinking. One of the simplest lecture demonstrations that can generate considerable discussion (and argument) between students involves two simple linear polarizing sheets. The sheets are cut into rectangular shapes with the polarizing axis at 45^o with respect to the sides (we call these unconventionally cut sheets “Swinaroid”). Even though the students are told that the sheets are nothing more than common linear polarizer, Swinaroid's apparently “strange” behaviour when one of the sheets is flipped over (see Fig. 2) can generate much healthy debate. This “tricky” lecture demonstration is a good introduction to a more serious polarization lecture demonstration where students are asked to “predict, observe and explain” light transmission through a series of plane- and circularly-polarized filters.

Lecture demonstrations can also be used to give students a concrete experience of things discussed in lectures. Fig. 3 shows an array of different items (glass preform, copper cable, fibre optics cables and connectors, fibre bundles, fibre sensors etc) collected over several years. Many students might only expect to hear about these items in lectures or at best see photos of them. By taking these items to class as a lecture demonstration, students have the opportunity to touch and play with them, and students' feedback suggests that they appreciate this opportunity. Such lecture demonstrations give a practical hands-on feel to what might otherwise be a fairly dry and theoretical presentation. Some of the more interested students often linger at the end of class, playing with the items and asking questions about their use.

Lecture demonstrations can be used to help visualize many photonics concepts. For example, the operational difference between single- and multi-mode fibres, and the dependence of mode order on propagation angle is often somewhat difficult to explain using the ray model of light. A Moiré pattern lecture demonstration using two overhead transparency sheets with periodic ruled lines can be utilised to represent the light waves reflecting through a waveguide. This simple demonstration can help students to understand these concepts. Again the "predict, observe, explain" technique can be used to get students thinking about the problem.

The concept of total internal reflection is another case in point. A laser pointer and a simple Perspex cylinder (Fig. 4) that is half-filled with cured Perspex and half-filled with smoky air can be used to very clearly demonstrate the phenomenon of total internal reflection. A computer simulation that complements the original demonstration can help quantify what was observed in the demonstration. The computer simulator “Raytrace”[12] is used in the photonics and fibre optics unit (both in lectures and one of the laboratory experiments). A U-shaped Perspex rod can be used to demonstrate total internal reflection and the effect of critical angle. Laser light is shone through one end of the rod and is channelled to the other end (via total internal reflection from the Perspex-air interface of the bent rod). The light is still observed at the distal end of the rod when the loop is immersed in water (since water has a lower index of refraction than Perspex), but when the loop is immersed in honey, the light is no longer channelled around the loop. The honey has an index of refraction that is similar to that of Perspex so the condition for total internal reflection is destroyed at the point where the rod is sharply bent. Again a computer simulator can be used to complement this demonstration.

Optical fibres or bent Perspex rods are not the only items that can be used to demonstrate channelling of light. Laser light shone through the side of an overhead transparency sheet makes an excellent demonstration of a planar waveguide. Light can also be channelled through a stream of water, but this recreation of Tyndall’s famous demonstration is both messy and very difficult to set up as a lecture demonstration (Fig. 5). In this case, a short video-clip movie of Tyndall’s experiment can be used as an alternative. The video-clip will never be quite as good as the *real* lecture demonstration, but the ease of accessing the video clip via computer CD ROM is an advantage. In addition, video enhancement techniques have been used to show the bending light path more clearly, and the video can be stopped or replayed as often as is required.

Finally, the concept of the wavelength dependence of fluorescence can be demonstrated very effectively with an overhead projector and some simple and commonly available materials. All that is needed are two sheets of transparent gift-wrapping cellophane (blue and orange) and a block of fluorescent Perspex (green). Initially the orange cellophane is placed over the screen of overhead projector. The Perspex block is placed in the transmitted orange light (which is concentrated about 6 to 8 inches above the screen), but even though the light is very intense, the Perspex block does not fluoresce. Next the orange cellophane is replaced with the blue one. The transmitted blue light appears to the eye to be much duller than the orange light, but the Perspex block fluoresces strongly with an intense greenish glow.

4. ON-LINE DISCUSSION FORUMS

The issue of motivating students so that they work regularly throughout semester is of major concern, especially when students have access to prepared lecture notes. The students' natural instinct is to deal with immediate, urgent deadlines at the expense of revising and consolidating yesterday's lecture material (especially if the exam is several months away). Regular problem-solving tutorials do help, but in the case of the photonics and fibre optics unit, there is no formal assessment of the quality of tutorial work (apart from the participation mark) and many students focus their attention rather narrowly around only the tutorial problems. Continual assessment in the form of supervised computer-managed learning (CML) tests does motivate students to study, but this assessment deals only with the laboratory component of the course. In addition to the issue of motivation, it is important that students be given the opportunity to develop and explore an interest in photonics that is beyond the topics covered in lectures. In past years, students were required to undertake a semester-long web-based assignment to help address these issues. It was consistently found that students seemed to do too little too late, and that plagiarism was a significant problem (though very easy to detect using web search engines).

In 2001, the web-based assignment for the photonics and fibre optics unit was replaced with a new pilot program where students were required to particulate in on-line discussion forums. The lecture class was split into three separate discussion groups (each with about 30 individuals). Each student was required to post at least two questions and two answers (to other students' questions) in their forum. Each forum was moderated by the lecturer, who would refocus discussions that had gone off track or make comments and suggestions where appropriate. The limited on-line discussions (which were conducted for about 30% of the course) were very successful. Many students commented that they found the on-line discussions interesting and useful. There was a wide range of contributions from rather unimaginative duplication of lecture material to very thorough and well-researched original contributions. All students were asked to submit their individual best question and answer for assessment. The moderator graded each work based on originality and correctness.

Here is one of the better examples (used with permission) from one of the discussion forums. The one-page response was concise, to the point and well written. The student (James) also included a textbook reference for further information. Here are some extracts from James' response to a question about how lasers are used to cool atoms. "Laser cooling of atoms involves slowing atoms down using atom-photon interactions… …an atom sitting in the light field will only react (strongly) if the photons in the light field are of a suitable energy to excite the atom to a higher quantum level". James then goes on to explain how an external cavity laser diode can be slightly detuned from an atom's (Rb) energy level transition. "Atoms sitting perfectly stationary in this laser field (which is detuned from the atomic resonance by a small amount) would not 'see' the light field and no interaction would take place. Atoms moving in the field however will see a doppler-shifted light field". Atoms moving with a component of their velocity towards one of the incident beams will absorb a photon form that beam. To conserve momentum this means that this component of velocity will be diminished. Of course, after some random time, spontaneous emission of the absorbed photon will take place, and … … will give the atom a velocity kick in a RANDOM direction. Thus, on average, the atom will be slowed down". James then went on to explain some technical details about how 3D laser cooling is achieved.

5. CORRELATIONS

The various forms of assessment in the photonics and fibre optics unit have been correlated against the raw examination results and are shown in Table 1. The correlations have been extracted from the data for 2000 and 2001. Where possible the results have been averaged over both years. The only obvious correlation that exists is for the CML tests. Students sit these multiple choice or short numeric format tests as individuals in a fully supervised mode and under similar conditions to the final exam. The CML tests students' problem solving ability and basic understanding of the photonics concepts underlying the laboratory work. It is therefore reasonable to expect a correlation with raw exam results. There is a lower but clear correlation between laboratory reports and discussion forums and raw exam results. In both cases the qualities being assessed differ significantly from those assessed by the exam. Also the level of student collusion in the reports and forums cannot be controlled, so a low correlation should not be unexpected. The web-based assignments had a very poor correlation to raw exam results and this, together with the fact that the assignments themselves were generally disappointing, has lead to the replacement of this assessment with the on-line discussion forums.

6. CONCLUSION

The second-year level photonics and fibre optics unit at Swinburne Univesity appears to be reasonably popular with students (from a diverse range of backgrounds) and is an effective introduction into this important technology. The use of power-point slides for delivery of the lecture material has allowed more time for lecture demonstrations, which are used to engage students in the learning process. On-line discussion forums (trialed as a 4 week pilot program in 2001) has had a good response from students, and it is hoped that on-line forums will help motivate students to work consistently throughout semester, rather than cramming for a few days before the final exam.

7. REFERENCES

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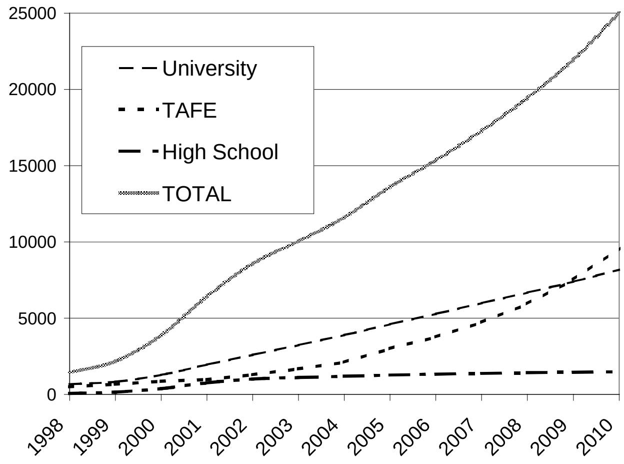


Fig. 1: Projected photonics employees (by level of qualification) required by the photonics industry in Australia over the next decade.

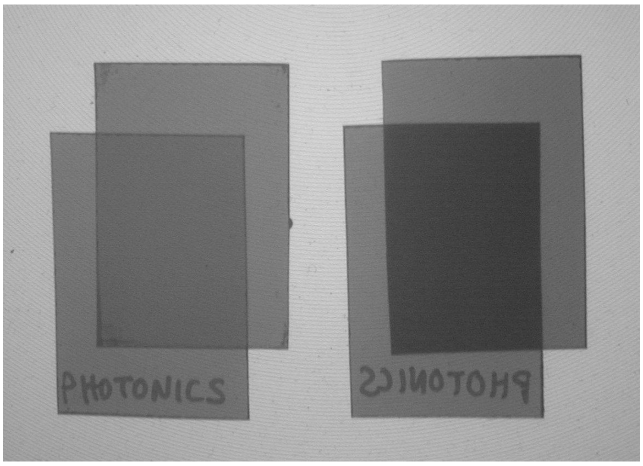


Fig. 2: "Swinaroid" plane polarising sheets, displaying *strange* behaviour when flipped.

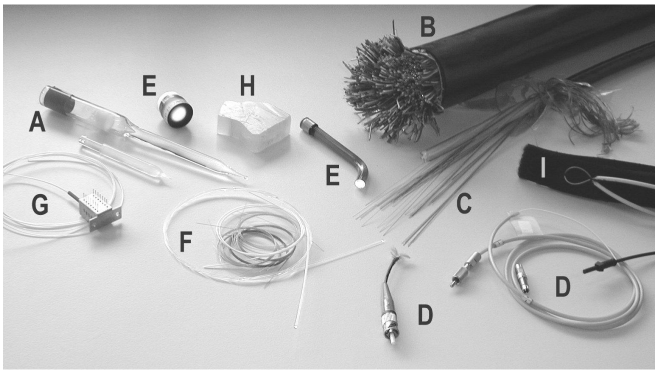
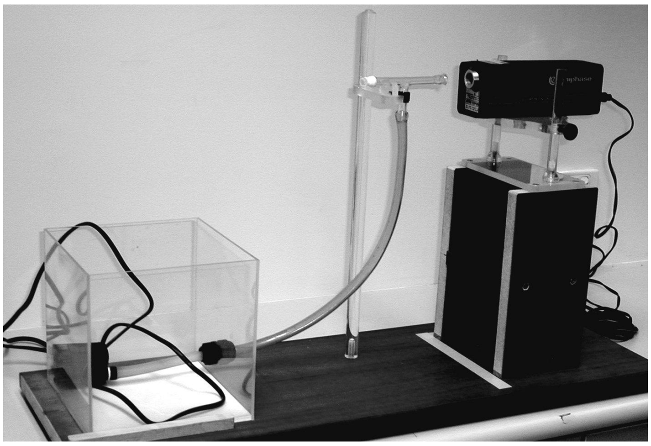


Fig. 3: Various items that can be used in photonics lecture demonstrations. (A) preform, (B) copper twisted-pair telecommunication cable, (C) optical fibre cable, (D) fibre optic connectors, (E) fibre optic coherent bundles, (F) glass and plastic optical fibres, (G) pig-tailed laser diode, (H) ulexite or television stone, (I) simple optical fibre displacement sensor.

Fig. 4: Perspex cylinder and laser pointer.



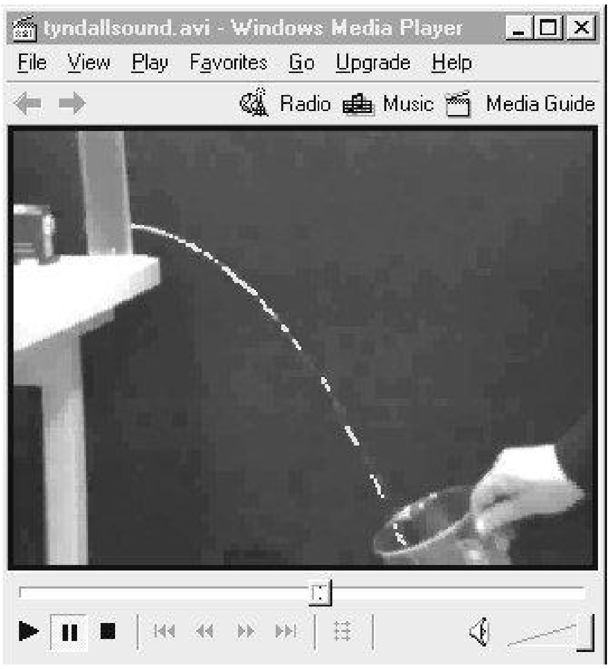


Fig. 5: *(above)*Apparatus for the recreation of Tyndall's experiment using a laser, glass T-piece and a small water pump.
(right) Video clip of Tyndall's experiment; video enhancement allows the channelled laser beam to be seen more clearly.

Mode of Assessment	**Correlation Coefficient**
Lab reports versus raw exam result	0.41
Web-based assignment versus raw exam result	0.17
Computer-based lab tests versus raw exam result	0.65
Discussion forums versus raw exam result	0.30

Table 1: Correlation coefficients
(Various forms of assessment correlated against raw examination results). N = ~ 90 students