Medical Physics Kickstart: designing a senior high school physics workshop.

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***Abstract**: A set of principles for the future design of senior high school physics workshops has been developed, with specific reference to medical physics. The principles address both specific challenges and misconceptions from the content, and general considerations related to the structure of the syllabus and therefore will provide a solid base for pedagogical design of workshops in other areas. Data were obtained from a variety of methods: Internet forum searches and focus groups with teachers and students were the main methods of research. The research indicated the key principles that need to be taken into consideration when designing the* Medical Physics Kickstart *session are: the four main syllabus problem areas of students, MRI, endoscope, ultrasound and diagnostic scans; the fact that many teachers do not have much experience in medical physics; and that teachers tend to teach the options last, after the core modules.*

Introduction

Students sitting for the NSW Year 12 Higher School Certificate in Physics study four topics: *Space*, *Motors and Generators*, *From Ideas to Implementations* and one option, chosen from five alternatives. Of these alternatives, *Medical Physics* is the second most popular (after *Quanta to Quarks*), with 27% of physics students studying it in 2006. Despite its popularity with the students, *Medical Physics* is a less traditional topic, and so resources at school level are as yet limited and many teachers are less familiar with the concepts than they are with more traditional areas, such as *Astrophysics* and *Quanta to Quarks*, which would have been included in their undergraduate study.

The NSW syllabus closely prescribes experiments which students should see or perform, presented as 'dot points'. However a number of these dot points require specialist equipment or have safety constraints which provide barriers to teachers performing them in the classroom. The *Kickstart* program, run by the School of Physics at The University of Sydney, seeks to address these challenges, providing three hour practical workshops in the School of Physics for students covering the dot points. These workshops have proved very popular, seeing over 2000 students in 2006. However, to date most of the *Kickstart* workshops are conducted on core material, with a small number of *Quanta to Quarks* workshops.

This study is the first formal research into *Kickstart*, and aims to identify common problems in the *Medical Physics* syllabus which will be used to come up with guidelines for the design of a *Medical Physics Kickstart* session. The research will also be used to come up with a set of general principles for the design of *Kickstart* sessions for all the options. In a broader sense the design principles can be applied to other teaching and learning interventions with similar goals to the *Kickstart* program.

Method

Much of the background material for this study came from the Board of Studies web site (Board of Studies NSW [online]) including the syllabus for *Medical Physics*, past examination papers and comments from the markers. The popular HSC textbook *Physics 2* (Andriessen, Pentland, Gaut and McKay 2002) provided a benchmark for the structure of the material. From this starting point the following methods were used to deduce the most common misconceptions and challenges.

Firstly, a search for literature on medical physics misconceptions was conducted. Secondly the Bored of Studies web forum was accessed (www.boredofstudies.org: see references), a very widely

used internet knowledge-sharing forum for students in their final year of school. This forum was selected for research as it has been established since 2002 and has around 30,000 members, and has specific sections for each discipline. The traffic to the site peaks in the latter half of the year, so this study, which was conducted as a first semester project, was not able to establish a significant dialogue with the users. Nonetheless the five years of archived posts provide a rich source of data.

The information gathered in the Bored of Studies forum was used to design a plan for two focus groups, one with teachers and one with students. The aim of the focus groups was to provide an open ended discussion in which the participants could bring up their opinions with little direction from the facilitator. Notes were taken by a separate person, and the forums were filmed for later reference.

For the teacher forum, we canvassed teachers who had brought classes to *Kickstart* in the past, thereby assembling a group of four teachers. Each participant had taught the *Medical Physics* option a number of times, and covered a range of genders and school types (public/private, large groups/small groups, gender mixes). The student group, also four strong, was comprised of volunteers (all female) from the first year physics students at the School of Physics. The focus groups began with open ended questions to promote free discussion and, if some topics had not yet been discussed, we moved on to more specific questions towards the end

The four applicable sources (Board of Studies, internet forum, teacher forum and student forum) provided a good range of data from which the themes could be extracted and analysed, with enough redundancy to provide triangulation for the results.

Results and discussion

The Board of Studies web site was very helpful in indicating exactly what the students were expected to know. The past examination papers with markers comments indicated the level of knowledge required from the students, they also highlighted commonly asked questions, which helped us determine which topics in the syllabus to focus on in our research.

The literature search uncovered very little relevant material. While there are a few papers addressing topics in medical physics, these are aimed at a higher level, mostly for university students enrolled in physics based courses within either medicine or medical science. The main resource at this level is the web site at Charles Sturt University (*HSC Online*).

Conversely the Bored of Studies forum was a rich source of data. In total there were 43 relevant threads in the medical physics forum. Among these threads, clear themes could be identified, and additionally the statistics for the number of replies and the number of views of each thread provided some quantitative insights into the importance of each topic: for example the Magnetic Resonance Imaging (MRI) related threads had the highest average number of views at 407.

While only a small group, the teacher forum was lively, as the group had a wide range of experiences to share. They represented hundreds of students over a number of years and as such their observations were highly reliable. Their familiarity with the *Kickstart* program also meant that their comments were particularly relevant. Not only did their comments on the content agree with the themes identified in the internet forum, but their perspective as teachers provided additional insight into the broader context of the *Kickstart* program in relation to classroom teaching.

The student focus group was the least reliable as there were only four students, all female and all of whom had gone on to study physics at university. As a result some of the data collected from them disagreed with the other research results. The key difference is that the focus group students tended to

have less difficulty with some of the syllabus areas than the forum students, this is reasonable as since the focus group students are studying physics at university and so they are likely to have been competent HSC physics students.

Specific content issues are summarised in Table 1. The study identified eight broad areas needing consideration when designing future workshops. These fall into two main groups; five related to specific medical physics content and three addressing more general themes. These eight themes are:

Table 1. A summary of the results gathered by the different methods

Areas of study / **Research methods**	**MRI**	**Scans**	**Endoscope**	**Doppler/ Ultrasound**
Internet Forum	Students had trouble understanding all the different concepts.	Students were unsure of the depth of detail required when comparing the scans.	Students understood the theory but not how to write answers to questions.	Students had more difficulty finding ways to do the required experiments.
Teacher Focus Group	Students need to see a real MRI machine, either in person or on a video, so they can see what all the theory culminates to.	Getting X-rays/ cat/bone of same body parts is hard	Students had trouble with the basic concepts of the endoscope, such as coherent vs incoherent light and fibre bundles.	A mini/portable ultrasound machine would be very useful in helping the students understand how the technology uses the Doppler Effect to obtain images
Student Focus Group	Resources were pitched at the right level. All the concepts they had to learn for the MRI were complicated	Images in text book are not as good as the real thing. The different types of scans were confusing	These students found the endoscope relatively easy.	Ultrasound was easy, because they studied it first.

Principles for Design of a *Medical Physics Kickstart* session

1. Magnetic resonance imaging

Magnetic resonance imaging emerged as a prominent area of difficulty throughout the study. Firstly it is a very large topic, consisting of a large number of separate concepts, which need to be synthesized to understand the whole MRI process. To compound the difficulties, concepts are very complex and non-intuitive, such as net spin, precession and relaxation time, which have not been explored in any detail in the core syllabus. An illustrative quote from a teacher: ‘Most understand how a proton has an alignment with the field but have difficulties understanding why it can align in two ways of different energy levels’. An additional point was raised in the student forum, where it was noted that the options are usually taught last, often in a rush to finish material before the examinations, whereas excursions to *Kickstart* usually occur earlier in the year.

It is clear that learning material for the MRI will need to be carefully structured, to address each concept in sufficient depth, yet at a level appropriate for students who had not yet covered the

material in class, while providing appropriate context for that concept in the overall workings of the MRI. The teacher forum felt that, as obtaining a full MRI machine is beyond the scope of *Kickstart*, including in the workshop a video of a MRI machine in use would be a valuable resource.

2. Endoscopes and ultrasound (Doppler Effect)
Endoscopes and ultrasound emerged as an area requiring attention, although students in both the internet and the student forums felt that they understood these concepts. Internet forum questions were not generally conceptual, instead focusing on how to express their answers: 'Explain how an endoscope works in relation to total internal reflection. How should I structure such a response?' Teachers did not share the students' confidence, perhaps reflecting that the students' inability to easily structure an answer indicated an incomplete understanding. The statistically small sample size of the student forum, biased towards stronger or more motivated students who continued with physics into university, may also account for this discrepancy.

The need for a *Kickstart* session on medical physics is demonstrated by the many internet posts requesting ideas for experiments or practical demonstrations (particularly in relation to the endoscope and the Doppler Effect). For example: 'Do any of you know an experiment method that uses reflected sound that shows the Doppler Effect quantitatively?'. While an MRI machine is beyond the scope of *Kickstart*, investment in endoscopes or ultrasound equipment could prove a worthwhile investment (that an individual school could perhaps not justify).

3. Scans
Much of the *Medical Physics* syllabus addresses imaging, and past examination questions ask students to compare different scan types. All participants in the study emphasised that there is a paucity of scans available, especially scans of the same area with different modalities to allow direct comparisons. There were also concerns about the quality of those that were available, noting that pictures in books or images on the internet were poor substitutes for the real thing, generally smaller and with questionable contrast and colour. A library of comparable scans that the students could see and hold during a *Kickstart* workshop was recommended, covering a range of modalities, and also illustrating the improvement of technology over time.

4. The human side of medical physics
As well as specific content, the senior physics syllabus specifies a number of generic outcomes. One of these refers to the impact of physics on society, and this is emphasised in the *Medical Physics* syllabus as well. While the use of video material (for example footage of MRIs) in the *Kickstart* workshops is not as captivating as having the equipment in the room, videos can address an added dimension if they include material that addresses the physics in society dot points. For example videos of scanning equipment in use and interviews or stories of the effect it has had on people's lives will bring life and relevance to the physics content.

Kickstart workshops do not currently include any video footage, as the focus is on practical demonstration, but this added resource should be considered. However it will not be an insignificant task to integrate video material into the dynamic nature of the workshops. An alternative approach may be to have the videos as a complementary resource, either sent to the teacher to use in the classroom, or available on the web.

5. Teacher's packs
One of the issues that arose in the teacher forum was that many teachers do not have a background in physics. For example a significant proportion of NSW teachers are biology teachers who have retrained to fill a gap in their school's skill base. Even fewer teachers have much knowledge of medical physics as until recently it has not been part of a standard undergraduate degree. Hence it

was recommended that a teacher's pack should be produced to support teachers who are attending *Kickstart Medical Physics*. Such a pack could be sent out in advance, with background material, pre-reading and any videos, scans or images used in the workshop, to allow the teacher to prepare the class for the workshop. This would also be useful for revision after the workshop.

General Principles for the design of *Kickstart* sessions for Syllabus Options

1. *Kickstart* workshops for options should be introductory
The first of the general principles has been already touched upon: the structure of the syllabus means that the options are traditionally taught last, which means that students attending *Kickstart* may not have covered the material in class – in some cases some of the optional material is not taught until after the trial examinations! Therefore workshops for options should be designed on the assumption that students participating in it will have no prior knowledge of the course. However, it must also be flexible enough to appeal to those few students who have already done the course and so do have an understanding of the course before they come to the session.

2. *Kickstart* workshops for options should not be exclusively tied to the dot points
Because of the prescriptive nature of the dot points, both the teachers and the students become very focused on ticking off each syllabus requirement. Hence the existing core workshops address the dot points quite specifically, as the students tend to dismiss material that is not directly relevant to the syllabus. However, as discussed above, students attending a *Kickstart* workshop on an option are likely to not be familiar with the syllabus, so the focus on dot points may not seem quite as relevant to the student. Instead emphasising broader appeal of the material (for example with the human stories discussed above in Point 4) or links to concepts from the core syllabus will better hold students' interest.

3. Supply teaching resources to the school where possible
Obtaining teaching resources is particularly difficult for the *Medical Physics* option (see above in Point 1), the teachers in the forum expressed a desire for any supporting material for the *Kickstart* workshops. It was felt that this would be of benefit not only for the year 12 classes, but could be used in earlier years' science classes as well.

Conclusions

Qualitative data regarding the difficulties in teaching the HSC *Medical Physics* Syllabus Option has been collected from a number of sources, with a number of different perspectives. From this data strong themes have emerged regarding the requirements for a *Kickstart* workshop. The strongest data came from the Bored of Studies internet forum and the teacher forum. Although the student forum was statistically small, the themes from the other sources were for the most part confirmed, providing good triangulation of our thematic analysis.

The content-related themes point to a strong requirement for in depth information on all facets of the MRI process, as well as practical modules for the endoscope and ultrasound imaging. These themes play to the current strengths of *Kickstart* as a practical workshop complementary to the classroom experience, while emphasizing that the structure and level of the material must be carefully considered to address the timing of the options in the academic year.

The paucity of resources for *Medical Physics* suggests a need for *Kickstart* to develop more dimensions, such as libraries of resources such as scans, images and videos. These perhaps could be incorporated into a wider learning process that includes pre-work and follow up material, delivered via the web or distributed to teachers to incorporate into their classroom curriculum. At the very

least, incorporating multimedia resources into what are currently exclusively practical workshops provides a good starting point for expanding the very successful *Kickstart* model.

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References

Andriessen, M., Pentland, P., Gaut, R. and McKay, B. (2003), *Physics 2: HSC course*, Wiley (Jacaranda).

Board of Studies NSW, *Essential educational resources for Australian teachers and students* [online] Available: http://www.boardofstudies.nsw.edu.au/ [2007, June 25].

Bored of Studies *Notes/Resources Science Physics* [online] Available http://www.boredofstudies.org/view.php?course=13 [2007, June 25].

Charles Sturt University, *HSC Online* [online] Available: http://hsc.csu.edu.au/ [2007, June 25].