Exploring the differences between students trained under the old and new HSC syllabuses

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1. Introduction

The School of Physics at the University of Sydney has a research group called SUPER, the Sydney University Physics Education Research group. In December 2000, an enthusiastic postdoctoral fellow, Dr Chris Stewart, joined SUPER. We considered possible research projects and decided to explore the differences between students trained under the old HSC syllabus with those trained under the new HSC syllabus. Of course we would use the sample most convenient for us, first year physics students at the University of Sydney.

In our research we ask whether the new HSC syllabus produces students who are well prepared for first year physics studies at our institution (note that we are not saying "better prepared"). Our findings are not generalisable to other institutions, and we are not attempting to compare the two syllabuses, for the following reasons.

The research is exploratory in the sense that we are trying to better understand the variables and the complex interplay amongst them. Our foremost aim is to use this understanding to provide learning opportunities at university that most benefit our students. In order to compare in a scientific manner we would need to control the remaining variables either statistically or experimentally. Even if we were able to achieve this, the study would need to be piloted and all the necessary statistical data collected.

Further, we are considering only students at the University of Sydney, so the sample is biased. We have not considered teachers experiences, and only one cohort from the old syllabus has been sampled. For all these reasons, we consider our project, experiences and interpretations to be a formative evaluation rather than a summative final judgement on which syllabus is better.

One of the first decisions we made was to use local expertise in the form of Associate Professor Mike Prosser and the SUPER group. The SUPER group assisted with brainstorming the design of the research study and focus on key issues while Associate Professor Prosser brought in his extensive research on student approaches to learning and conceptions of disciplines.

2. The research methodology

One consequence of the formative nature of our evaluation is that the project has combined approaches used in qualitative and quantitative research. The major *qualitative* feature is that the research methodology has evolved and our observations have identified themes and generated questions. The major *quantitative* feature is that we investigate statistical differences using established measures. In this section we outline the initial study, and how the study has evolved, emphasising the qualitative and quantitative features. An evolving research methodology is particularly useful in identifying facets of the phenomena that are not initially obvious.

2.2 The initial study

Initially our project consisted of two large surveys to be delivered in 2001 and 2002. The first survey administered early in first semester of first year to capture students' high school experiences and the second early in second semester of first year to capture students' university experiences. Thus we address our aim by investigating if students are well prepared for first year physics studies at our institution and how we influence them during one semester of interaction at university. So far we have focused our analysis on the former aspect.

The first survey consisted of the following three parts:

a. A Likert scale survey on students' *conceptions of physics*, generating quantitative data indicating whether students perceive physics as a coherent whole or as fragmented pieces.
b. A Likert scale survey on students' *approaches to studying physics*, generating quantitative data indicating whether students use deep or surface approaches to studying physics.
c. *Open-ended questions* based on our interpretation of the changes in the HSC physics syllabus. The data is qualitative and the analysis has been selected to identify variations in student responses.

In this paper we present results of the Likert scale surveys (a and b) for 2001, 2002 and 2004 and only two open-ended questions (c) for 2001 and 2002.

2.3 Additional facets of the study

We have become aware of three important concerns about the new HSC syllabus amongst the physics education community: first, that it does not allow for as much understanding of concepts as the old syllabus; second, that the new syllabus is not as mathematically rigorous; and third, that the new syllabus does not cater for the best physics students. You are all high school physics teachers and we invite you to provide your own insights and concerns that we can incorporate into our study.

We could not address the concerns directly, but continuing the list above, we have used the following methods to further the discussion:

d. Administering the *Force and Motion Concept Evaluation* (FMCE), a test that generates quantitative data, to find out if there has been a statistical change in students' understanding of concepts;
e. Tracking changes in student numbers in the School of Physics;
f. Carrying out an initial qualitative content analysis of the HSC physics syllabus
g. Identifying the levels of mathematics required for various first year courses in the School of Physics at USYD; and
h. Systematically collating the qualitative anecdotal evidence that we have been accumulating since 2002.

Ideally we should survey teachers and academics about their experiences with the new HSC physics syllabus and talk to students as they progress through their university physics studies. The later group is particularly important as we can investigate the experiences of students whose foundations of physics have been provided by the new syllabus. At this stage, however, we have not explored these possibilities.

In this paper the results of the FMCE (d) for 2001, 2002 and 2004 are presented in the same section as the results of the Likert scale surveys. Trends in student numbers (e) from 1999 to 2004, and results of a content analysis of the old and new HSC syllabuses (f) are discussed. However, we leave (g) and (h) for our presentation.

3. Analysis and Results

In this section we focus on the results rather than technical details about analysis. Please contact us for more details about the research.

The School of Physics at the University of Sydney streams first year physics students in first semester according to their high school experiences of physics:

- *Fundamentals* for students who have not done HSC physics or who scored less than 65 in HSC physics;
- *Regular* for students who have done well in HSC physics; and
- *Advanced* for students who have done HSC physics and have a UAI more than 95, or HSC physics mark of more than 90 irrespective of their UAI.

These are mainstream physics courses and students from all these streams can carry on to do physics in later semesters.

3.1 Likert scale surveys and the FMCE

In this section we present analysis of the qualitative surveys given to the 2001, 2002 and 2004 Regular student cohorts. We have chosen this group because the number of student responses is large enough to allow a statistical analysis. We have used several statistical tools; in this section we concentrate on the *cluster analysis*, a method of grouping students into 'clusters' with similar patterns of survey responses.

The students were given questionnaires to measure their preferred approaches to learning physics, with one scale measuring a *deep approach* that emphasises consolidation of concepts and making links between ideas, and one measuring a *surface approach* that prefers memorisation and rote learning. The students' conceptions about the nature of physics were also surveyed, with one scale measuring a *cohesive conception*, in which physics is seen perhaps as a holistic framework to describe phenomena, and one measuring a *fragmented conception*, where physics is seen, for example, as a collection of unrelated facts and theories. We have applied a clustering algorithm that groups students according to their scores on five variables: the four scales above, and their scores on the FMCE.

Similar studies in the past have uncovered two common groups of students:

- An *Understanding* group, in which students' responses indicate that they think of physics as a coherent whole and use deep approaches to studying physics; and

- A *Reproducing* group, in which students' responses indicate that they think of physics as fragmented elements and use surface approaches to studying physics.

In addition, two other groups have appeared in several studies:

- A *Disintegrated* group in which students' responses indicate that they think of physics as *both* cohesive whole and fragmented, and report they use *both* deep and shallow approaches to studying physics. This group's responses is considered *dissonant* or *disintegrated*, since these different conceptions of physics and approaches to learning are thought to be mutually exclusive (though other interpretations are possible); and
- A *Disengaged* group, in which students' responses suggest they do not identify strongly with either a cohesive or fragmented conception of physics, or take a surface or deep approach to learning the subject. It is possible this group is reacting to the survey instrument itself, or that they are *disengaged* from the learning process.

Previous research studies have shown that the *Understanding* group scores well on average on tests of their conceptual understanding of physics. Conversely, the *Reproducing* group show poorer conceptual understanding. In those studies, however, the *Disintegrated* group performed worst of all, in agreement with the interpretation that these students are confused about their learning. In our study we gave students the FMCE, testing their understanding of Newtonian physics concepts. Figure 1 shows the average score on this test for each cohort of Regular-stream students, as well as the average score for the 2004 Advanced students (this group was not given the test in previous years).

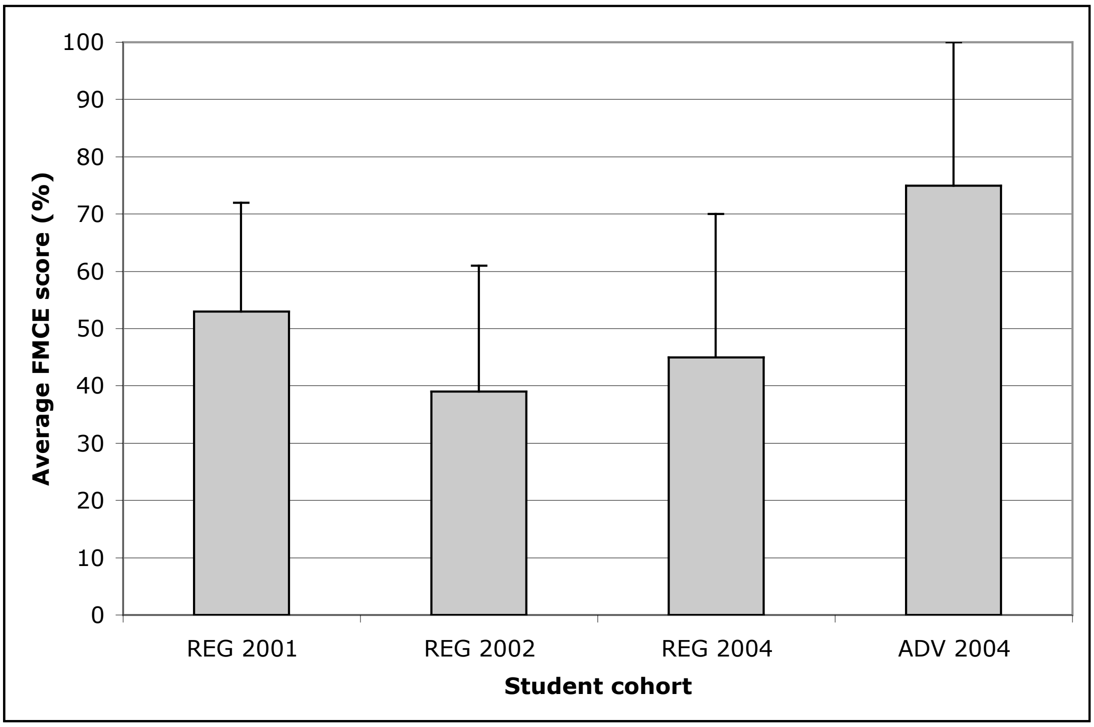

Figure 1: Average FMCE score for Regular-stream students in 2001, 2002 and 2004, and Advanced students in 2004. Error bars represent one standard deviation.

A significant drop in average FMCE score occurred between 2001 and 2002 (z-test, $p < 0.01$), but the score increased significantly again ($p < 0.01$) in 2004. The Advanced stream students, by comparison, score much higher on this test.

We found evidence for all four groups mentioned above, though not all appeared in each cohort. Figure 2 shows a breakdown of the Regular cohorts into the four characteristic groups, according to the cluster analysis.

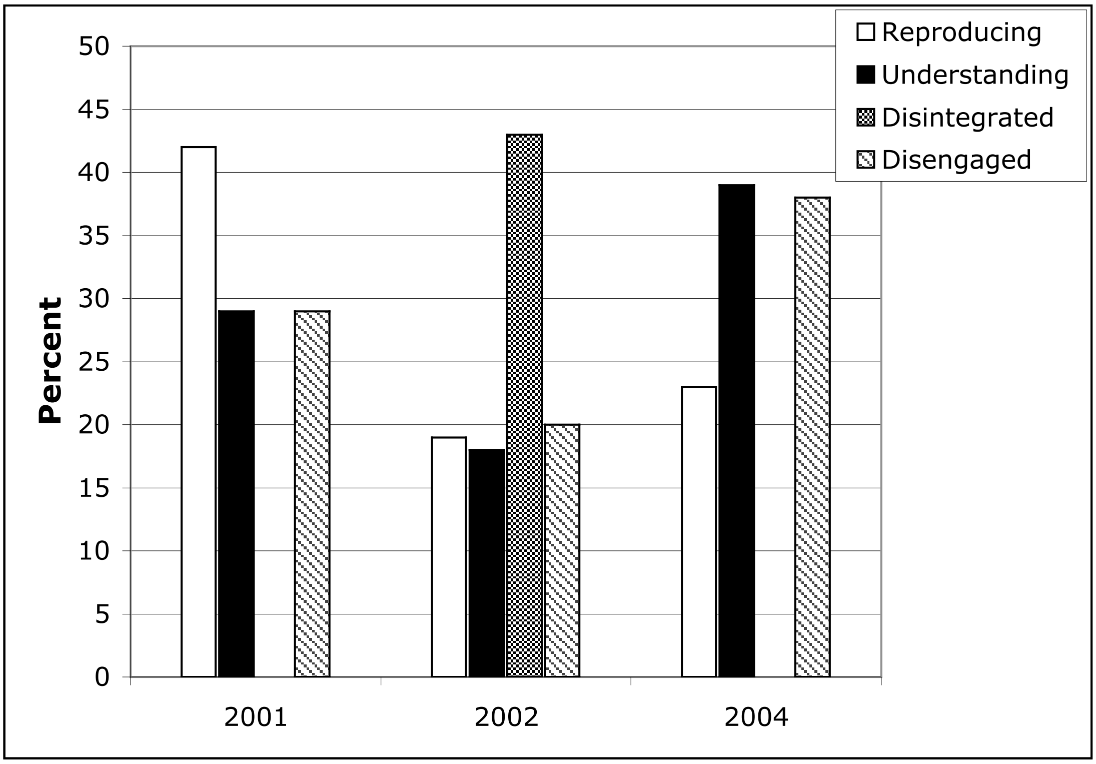

Figure 2: Clusters of students with similar patterns of responses, as a percentage of the entire Regular stream cohort.

We make several observations about these results. First, we see that the *Disintegrated* group, absent in 2001, appeared dramatically in 2002. By 2004, this group has disappeared again. (Actually, the identification of the groups in 2004 is not clear-cut — the *Reproducing* group in 2004 has characteristics of the *Disintegrated* group. But even if all of these students fall into the *Disintegrated* group, the group size has certainly dropped significantly since 2002.)

We interpret the emergence of the *Disintegrated* group as a sign of the inherent confusion in the classroom, and in students' minds, in the wake of substantial syllabus change. The 2002 cohort was the first taught primarily under the new HSC syllabus. The large proportion of students that year (almost 45%) with a dissonant collection of approaches to learning and conceptions about the nature of the subject may be the product of confusion in the classroom, due perhaps to teachers lacking in confidence, a scarcity of classroom materials and textbooks, and general uncertainty about assessment practices and expectations. The decrease in size (or absence) of the *Disintegrated* group in 2004 suggests to us that, as the syllabus gets fine-tuned, as teachers gain confidence and resources, and as the HSC assessment practices become familiar, students experience less confusion about their learning.

Second, we see that the proportion of students in the *Understanding* group has grown in 2004, compared with the 2001 cohort. This is a pleasing result, given the aim of this study: to see whether students are prepared for studying physics at university. We argue that the characteristics of the *Understanding* group are those most physicists would consider to be suited to developing a solid training in physics; if our results are accurate, we have more "good" students in 2004 than prior to the syllabus changeover.

Our third observation concerns the FMCE scores for the different groups. We expected the average FMCE score to be highest for the *Understanding* group, lowest for the *Disintegrated* group (with the *Reproducing* and *Disengaged* groups falling somewhere between). This pattern was observed in 2002 and 2004, but in 2001 was reversed — that year, the *Understanding* group did significantly worse on the FMCE than the *Reproducing* group. We admit that, at present, we do not understand this result.

3.2 Open-ended questions

The two open-ended questions we considered differentiate between the contextual and traditional focus and are shown below.

Q1: Much of physics is about the way things move and changes in motion. What do you know about the physics of motion?

Q2: There is a lot of Physics that relates to the way people communicate with each other. What do you know about this?

Our first hypothesis was that students trained under either syllabus would answer in much the same way to question 1 as it is about a specific knowledge area of physics. Our second hypothesis was that students would answer in different ways to question 2. We did not hypothesize in what ways they would be different. We were interested in categorising differences and similarities in the answers for the two years so we used an approach known as phenomenography. Three researchers categorized the answers independently to ensure that variations and similarities were identified and that our interpretations of student answers were not biased. Table 1 summarises the categories for Q1 and table2 for Q2. Using Chi-squared statistics, we found no significant difference between 2001 and 2002 for Q1. However the distributions were statistically different for Q2.

Category	**Percentage for 2001 (*n*=325)**	**Percentage for 2002 (*n*=420)**
No useful information	20.0	20.9
List-like	54.1	56.9
Linking ideas	25.9	22.2

Table 1: Summary of the results of phenomenographic analysis of student answers to question 1.

Category	Percentage for 2001 (*n*=234)	Percentage for 2002 (*n*=237)
No useful information	50.4	36.3
List-like	25.6	24.9
Linking ideas, coherent	12.4	24.9

Table 2: Summary of the results of phenomenographic analysis of student answers to question 2.

How were the answers to Q2 different in 2001 and 2002? We found subcategories (within the category *linking ideas and coherent*) of answers in 2002 that were not found in 2001. The following quotes exemplify the new categories:

- *The physics of telecommunications, satellites and other modes of communication is a broad and in-depth subject that touches on many areas of science, not just physics. (2002)*
- *The principles of physics underline most of the technology that people use today to communicate with each other. The study of optics, waves etc. satellite communication, the use of the telephones, computers/internet (2002)*
- *Physics discoveries lead to development of mobile phones, optic cables, all communications devices because of electric circuits, energy. (2002)*
- *Satellites, telephones, everything in communication is related to the transmission of information which all has a basis in Physics. (2002)*

Some students amongst the 2002 cohort have chosen to explicitly answer the question by demonstrating the relevance and utility of physics. As this is a major feature of the new syllabus it is rewarding to see such student answers. In comparison such a category was not identified in 2001. Hence our interpretation is that students exposed to the contextual syllabus are more tuned to the utility of physics.

3.3 Keeping track of changes in student numbers.

The numbers of students enrolled in the Fundamentals stream varies from 200 to 280 while those in Regular from about 420 to 490. The numbers in the Advanced and higher years is shown in table 3. About a third of the students in higher years are from the First Year Regular stream, a few from Fundamentals and the remainder from the Advanced stream. A large fraction of First Year Physics students, such as those enrolled in engineering, medical science or intending to major in another science, have no intention of doing further courses in physics.

The First Year Advanced student numbers have been increasing steadily while the Second and Third Year numbers have been increasing since 2003. We have not been able to explain why the Third Year numbers increased in 2003, but we are very pleased that they did. On the whole, the trend has been increasing student numbers with the new HSC physics syllabus. It is highly likely that there are other contributing factors, such as an increase in students choosing to do double degrees.

Year	First Year Advanced	Second Year	Third Year
1999	83	84	38
2000	99	92	41
2001	117	83	44
2002	142	83	47
2003	174	106	68
2004	185	127	71

Table 3: Numbers of students in First Year Advanced, Second Year and Third Year physics courses at the School of Physics, University of Sydney from 1999 to 2004. Note that the Second and Third Year numbers include students in the mainstream Regular and Advanced courses.

3.4 Content analysis of the HSC physics syllabus.

We have done a simple content analysis of the old and new HSC physics syllabus. This is just an analysis of the syllabus document, and by no means a reflection of what occurs during the teaching and learning process. We needed to select a criterion for the content analysis so we decided to consider the aims of secondary education in NSW stated at the start of the old HSC syllabus document and how these are addressed by the core year 12 physics syllabus.

> *The central aim of education which, with home and community, the school pursues, is to guide individual development in the context of society through recognisable stages of development towards perceptive understanding, mature judgement, responsible self-direction and moral autonomy.*
>
> -Aims of Secondary Education in NSW, November 1973.

Within the old HSC physics syllabus document four themes are identified and expanded as follows.

i. *Guide individual development* in terms of acquiring skills and exposure to a variety of learning experiences.
ii. *Context of society* in terms of understanding historical development, the influence of science on community, the role of science in technology etc.
iii. *Recognisable stages of developmen*t in terms of understanding concepts and knowledge and acquiring skills.
iv. *Perceptive understanding, mature judgement, responsible self-direction and moral autonomy* in terms of acquiring critical thinking, using scientific method, being receptive and accepting responsibility.

The themes are then translated into the following three areas that are to be addressed in the physics syllabus.

- Knowledge and understanding incorporates theme (iii).
- Skills incorporates aspects of (i) and (iii) and (iv).
- Values and attitudes incorporates aspects of (ii) and (iv).

Table 4 shows the Core Year 12 Topics in the 1995 Physics Stage 6 Syllabus and the extent to which our content analysis shows that each area is covered in the topic descriptions. Table 5 does the same for Core Year 12 Topics in the 1999 Physics

Stage 6 Syllabus We have chosen three descriptors, very explicit, explicit and not explicit.

Core topic	knowledge and understanding	skills	values and attitudes
Describing Motion II	very explicit	explicit	not explicit
Forces II	very explicit	explicit	not explicit
Mechanical Interactions II	very explicit	explicit	not explicit
Electrical Interactions II	very explicit	explicit	not explicit
Electromagnetism	very explicit	explicit	not explicit
Waves II	very explicit	explicit	not explicit

Table 4: The Core Year 12 Topics in the 1995 Physics Stage 6 Syllabus and the extent to which an area is explicitly covered in the documentation.

Core topic	knowledge and understanding	skills	values and attitudes
Space	very explicit	very explicit	explicit
Motors and Generators	very explicit	explicit	explicit
From Ideas to Implementation	very explicit	very explicit	very explicit

Table 5: The Core Year 12 Topics for in the 1999 Physics Stage 6 Syllabus and the extent to which an area is explicitly covered in the documentation.

We note the following points about the old HSC syllabus.

- The syllabus is traditional in the way the content is listed and experiment work is titled *suggested experiences*.
- None of the topic descriptions contain detail on theme (ii). Electromagnetism had *replication of Oestard's electromagnetic experiment* as a suggested experience. Core 6, Nuclear Physics, of the Preliminary Syllabus contained work on Rutherford's experiment and a suggested experience was *debate the future of nuclear energy*. In some HSC Electives there was a greater possibility of developing a historical perspective. The role of science in technology and society was not mentioned. Nor have applications or links with technology been explored.

We note the following points about the new HSC syllabus.

- The syllabus document is more prescriptive and the approach is contextual. Three broad topics are covered including 20th Century physics.
- Physics is presented as a dynamic and evolving field. Skills include students gathering and presenting secondary information, performing investigations and discussing viewpoints. Real life applications and links with technology are included.
- The overview formulates that *contexts* are used to increase motivation and *focus areas* to emphasise applications.

One point about the focus on skills, values and attitudes in the new syllabus deserves mention. The Faculty of Science at the University of Sydney has developed a statement outlining a set of "generic graduate attributes" developed over the course of a university science degree (see web site 2): research and inquiry; information literacy; personal and intellectual autonomy; communication; and ethical, social and professional understanding. These attributes are best developed in a discipline context. According to tables 4 and 5, the new HSC physics syllabus initiates training in areas identified by the University, and by employers, as desirable “generic attributes” of a university graduate.

With such an increase in the *explicit* focus on values and attitudes, and arguably skills as well, one might expect that ‘something has to give’ in the HSC physics syllabus. Our research gives some indication of where that ‘give’ may be found: for one thing, the students’ FMCE results suggest a decrease in their conceptual understanding of Newtonian mechanics. However, the FMCE scores increased from 2002 to 2004, indicating that at least some of this drop was due to the syllabus *implementation*, and not entirely to the syllabus itself.

Certainly, we have seen no indication that students are not coping with university physics courses. We have not needed to change the pace or decrease the content of our lectures, labs or tutorials, or the difficulty of our assessments and exams. In addition, we have anecdotal evidence that the students’ are more able and willing to discuss ideas and work collaboratively to solve problems.

4.0 Discussion

We have deliberately chosen not to write a conclusion. Our research is about exploring and understanding the learning experiences of students who undertake further studies in physics at the University of Sydney. The students are enrolled in a wide number of degree programs; for example, students enrolled in First Year Advanced can be enrolled in one of 16 degree programs, while those in Third Year Advanced in one of 6 degree programs. Upon graduating the students are employed in a diverse range of careers, including finance and management, computing and engineering, international research positions and teaching. The training the School of Physics provides needs to be valuable to all graduates in their future endeavours. Hence there is a need to understand what the students are like when they start studying physics and what are they like when they finish.

From our research so far we can make the following statements about what the students are like when they start studying physics at the University of Sydney. These statements are not directly comparing the old and new physics syllabuses. However the results can be used to reflect on the transition;

- In 2004 approximately 40% of the Regular students thought that physics is a coherent body of knowledge and used deep approaches to studying physics, while in 2001 approximately 30% reported such approaches. In 2002, student perceptions were very confused.
- The average FMCE scores for the Regular cohort decreased from 2001 to 2002 but have increased again.
- In 2002 a group of students chose to report on the utility and relevance of physics in responding to our survey, while in 2001 similar reporting was not found. The 2002 students are more aware of the role of physics in technological advances and the dynamic nature of physics.

- Student numbers in mainstream physics courses for all years have been increasing. We are yet to see if this translates into more students doing postgraduate studies — we will get some idea after this wave of new students graduates this year.
- The structure and goals of the Physics Stage 6 Syllabus leads naturally to further developing the non-discipline-specific, "generic" graduate attributes of students while teaching physics at university.

In summary, our results show that there has been some confusion amongst students about their learning of physics during the transition from the old to new syllabuses. However the confusion is receding as the new syllabus settles in. We see no evidence to suggest that students are not coping with university-level physics – indeed, student numbers are increasing, and the new HSC syllabus may be a contributing factor.

6.0 Acknowledgements

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7.0 References

Web site 1
http://www.boardofstudies.nsw.edu.au/syllabus_hsc/syllabus2000_listp.html#pdhpe

Web site 2
http://www.itl.usyd.edu.au/GraduateAttributes/facultyGA.cfm?faculty=Science

For additional references please contact the authors.