

Is there a problem with NCEA Physics 3.6?

An electrical engineering perspective

Schools are in need of simple and reliable circuits that are easy to set up for classroom experiments, write University of Canterbury academics ANDREW LAPTHORN, SHREEJAN PANDEY and YUSUKE HIOKA.

In recent years the number of students taking the Electrical and Electronics Engineering (EEE) programme at the University of Canterbury (UC) has declined, despite strong numbers in engineering as a whole.

A similar trend has been noted at The University of Auckland, which has seen a reduced cut-off grade point average for EEE, compared with other programmes. However, industry demand for qualified EEE engineers is still high and there is genuine concern that universities will not be able to meet the needs of industry if this trend continues.

Anecdotal evidence from some of our students suggested that the electrical component of NCEA physics is possibly too difficult and may be deterring potential EEE students. Some said that the electrical component of NCEA physics is not even taught at their

schools so they taught themselves because of their interest in the subject.

Survey results highlight curriculum issue

Concerned about this enrolment trend and the anecdotal evidence, we investigated possible causes. This involved surveying engineering students at both UC and UA, analysing data for secondary school pass rates in NCEA physics, and holding focus groups with secondary school physics teachers. We aim to highlight a potential problem with the NCEA physics curriculum and invite discussion and debate around ways to improve it.

Two separate surveys were conducted, the first of which involved first-year Bachelor of Engineering students at UC. This group included students who are interested in all the engineering disciplines offered at UC. The second group consisted of EEE and mechatronic students from both UC and UA.

Mechatronics was chosen for the study as there is common ground between EEE and mechatronics (mechatronics being placed between electrical and mechanical engineering). We were interested in why the students chose engineering, what influenced their choice, and what type of engineering they intend to pursue.

As part of UC's first-year Bachelor of Engineering study, students are required to take a compulsory ENGR101 'Foundations of Engineering' paper before committing to their

choice of professional engineering discipline in their second year. ENGR101 enrolments provide a good cross-sectional sample of students who retained their interest in sciences and mathematics at secondary level.

At the end of class tutorials over a one-week period, 112 of approximately 800 ENGR101 students were asked to respond anonymously to 21 multi-choice questions in three parts: 'General'; 'Motivations for Pursuing Science and Engineering Study'; and 'Career Path'.

Survey results of the motivational factors behind pursuing engineering are shown in Figure 1 and highlight that career potential 'definitely' influenced the majority of respondents (62 per cent).

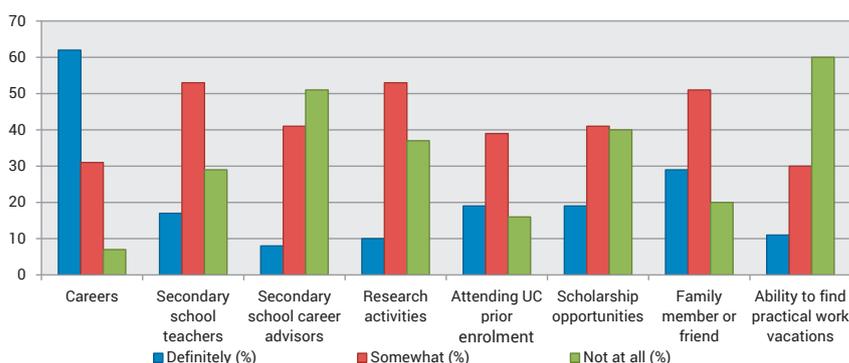
Secondary school influence minimal on first-years

What is of particular interest is that only 17 per cent of first-years were 'definitely' and 29 per cent were 'not at all' influenced by their secondary school teachers. Similarly, only a small 8 per cent were 'definitely' and 51 per cent were 'not at all' influenced by their high school careers advisors. These figures indicate that students who choose to pursue an engineering degree are usually career motivated and both secondary school teachers and career advisors only minimally influence their choices.

See Figure 1: Motivational factors for engineering studies.

See Figure 2: Degree preferences of the first-year engineering student sample.

1: Motivational factors for engineering studies.



2: Degree preferences of the first-year engineering student sample.

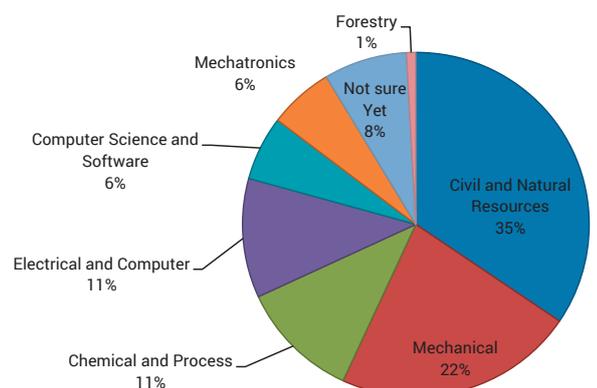


Figure 2 shows the respondents' preferred choice of study in completion of their engineering intermediate year. Electrical and computer (11 per cent) is a third-equal choice of study following civil and natural resources (35 per cent) and mechanical (22 per cent) engineering degrees. A considerable proportion (8 per cent) had not decided their choice of study and some may choose to pursue EEE.

EEE and mechatronics student surveys

In the second survey, three cohorts of students from UC and The University of Auckland (UA) were surveyed anonymously: at UC, 34 third and fourth-year EEE students and seven third-year mechatronics students; at UA, 37 third-year mechatronics students.

Survey questions

- » In which stage of education (e.g. school year) did you decide to study electrical and electronics engineering/mechatronics?
- » What was the most important factor for you to decide to study electrical and electronics engineering/mechatronics?
- » How did you collect information to make a decision to study electrical and electronics engineering/mechatronics?
- » What factors influenced your decision to study electrical and electronics engineering/mechatronics? Please elaborate.
- » Did you consider any other disciplines in engineering as your speciality? If yes what disciplines were they and why? If not, why not?
- » What are your career aspirations? At the completion of your undergraduate study, do you want to be a specialist or a generalist?

Contrasting results

In question 1, all mechatronics students at UC made their decision in the first year of university, in contrast with the majority of EEE students at UA, who made their minds up in high school.

See Figure 3: Question 1 results.

See Figure 4: Questions 2 and 4 results.

The most prevalent answer to questions 2 and 4 around influencing factors was interest in the particular discipline, followed by job opportunities or high income potential.

However, around a third of mechatronics students specified the broadness of the discipline as the main contributing factor to their decision, in contrast to the EEE students.

When asked in question 5 about any other disciplines that the students had considered, mechanical engineering was the most popular option across all three cohorts. It should also be noted that mechatronics was also a strong candidate for the EEE students, whereas computer/software engineering was more popular with the mechatronics students than with the EEE students.

One significant difference between EEE and mechatronics students is the number of 'none' answers ('none' meaning the student did not consider any other specialisation options): only about a third of the EEE students answered 'none', whereas the majority of mechatronics students had considered several different options.

See Figure 5: Question 5 results.

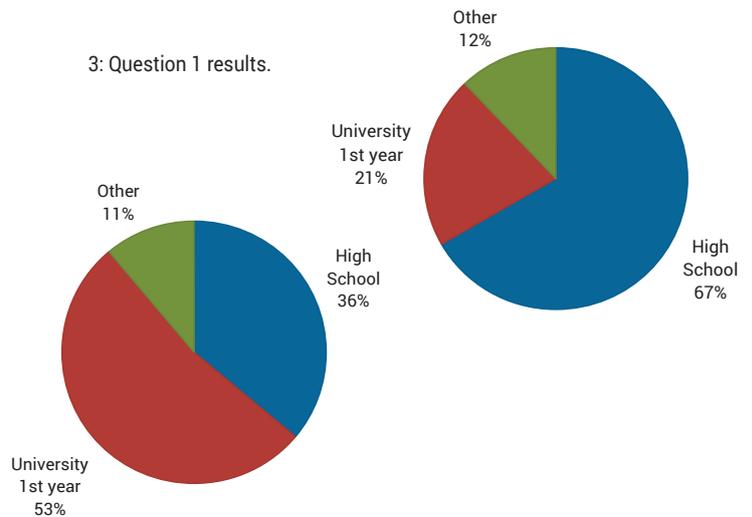
Looking for year 13 electrical systems AS numbers

Universities require students to have completed Level 3, 10 literacy credits at Level 2 or above, 10 numeracy credits at Level 1 or above and three subjects at

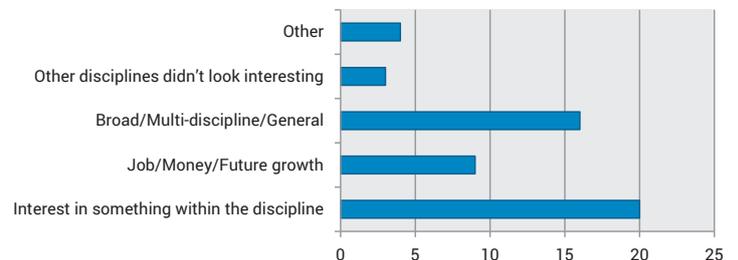
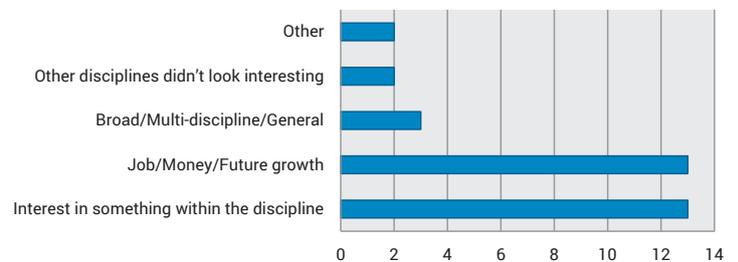
Level 3, made up of 14 credits each, in three approved subjects (New Zealand Qualifications Authority, 2014).

UC's engineering college requires students enrolling in the first year of the engineering programme to have 14 credits in Level 3 calculus or mathematics, physics and chemistry, with 18 credits recommended. To get into the EEE programme a student does not require chemistry.

3: Question 1 results.



4: Questions 2 and 4 results.



IN A NUTSHELL...

Concerned by declining numbers in the Electrical and Electronics Engineering (EEE) programme at the University of Canterbury, we investigated the causes by surveying engineering students. The surveys found that students are generally motivated by career opportunities and also showed that the majority of students studying EEE made their decisions at secondary school.

Enrolments dropped for year 13 calculus and physics (important subjects for engineering) after the introduction of NCEA, followed by a slow recovery. This suggested a reduction in the number of students available to choose engineering at university.

A closer look at the electrical NCEA Level 3 physics external achievement standards revealed an unusually high void rate for the external electrical component (3.6), compared with 3.3 (waves) and 3.4 (mechanical). This suggests students find the electrical component more difficult.

Finally, focus groups held with local physics teachers revealed that the electrical assessment is based on outdated technology and should be updated to suit modern environments that appeal to secondary students.

These focus groups also revealed that 3.6 is considered to be the most difficult of the three external topics and schools are in need of simple, reliable circuits that are easy to set up for classroom demonstrations and experiments.

We are interested in the number of students opting to take physics in year 13. Moreover, we are particularly interested in the number of students who opt for the 'electrical systems' achievement standard (AS) in year 13.

In order to understand enrolment numbers in secondary school mathematics and physics, we obtained 'Secondary schools enrolment data for the past ten years by subject' and 'NCEA Physics Results for Levels 1 to 3' from the Ministry of Education (MoE) and the New Zealand Qualifications Authority (NZQA) respectively.

The data was used to obtain absolute year 13 calculus and physics enrolment numbers and trends. It was also used to identify NCEA 3.6 (electricity) examination results, and compare them against other external examination results.

Rising physics enrolments not reflected in EEE numbers

Figure 6 presents year 13 enrolment trends in secondary physics and calculus at a national level. The decline in enrolment between 2003 and 2005 coincides with the introduction of

NCEA Level 3 replacing bursaries in 2004.

Based on discussions in sections to follow, it is the authors' speculative assertion that the decline may have been related to physics and calculus being perceived as the more difficult subject by students who wished to limit their risk of 'Not Achieved' Level 3 credits at a time when NCEA was first introduced.

See Figure 6: Year 13 physics and calculus, number of students enrolled in each course.

Overall, year 13 enrolment numbers in calculus and physics are rising, which is likely to lead to a greater number of tertiary level engineering students, but have still not fully recovered (especially in calculus).

However, the following sections present findings and discussion on why rising enrolment numbers in year 13 physics may not necessarily result in more students pursuing EEE degrees.

NCEA physics and electricity achievement standards

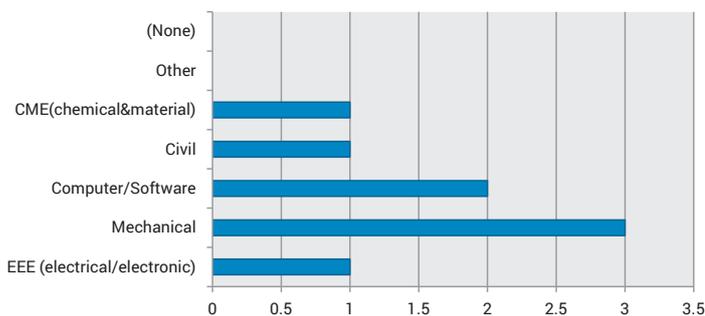
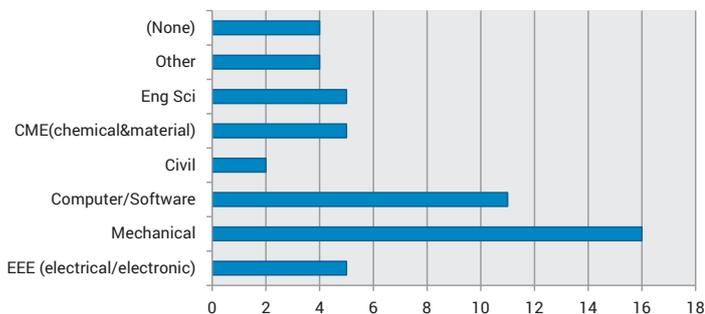
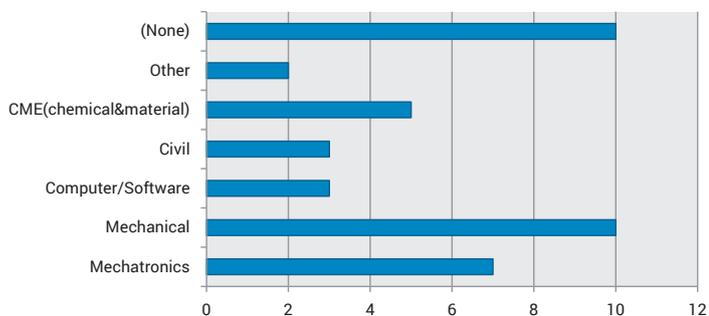
See Figure 7: NCEA physics, number of students enrolled in external AS.

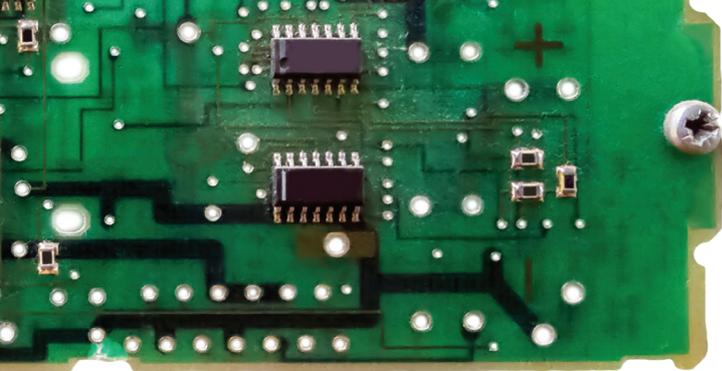
Figure 7 shows a comparison between the number of students sitting the external achievement standards (Ex ASs) in NCEA physics from 2009 until 2013 for each level and the number taking the electrical-based Ex AS. This data gives an indication of how many schools are teaching the electrical component of NCEA physics. There are a number of conclusions that can be drawn from this data.

- » There is an overall trend of growth in student numbers for each level of physics, which is consistent with Figure 6.
- » There is a reasonably significant drop in student numbers between Level 2 and Level 3, suggesting failure in and/or discontinuing of physics for some students. However, the number appears to be constant and combined with the growth in overall student numbers represents a decreasing percentage in attrition of Level 3 physics students.
- » The electrical Ex AS appears to be widely taught, with nearly all students taking physics also taking the electrical component, especially in Level 3.

This is largely encouraging news for the EEE programme. More students taking physics and calculus is likely to translate into more students enrolling in the EEE programme.

5: Question 5 results.





Unfortunately, if one digs a little deeper some troubling trends begin to emerge. Figure 8 shows pass rates for NCEA 3.6 from 2009 to 2013. Two of the categories of this plot benefit from some explanation. Firstly, 'Absent' represents the number of students who did not show up to the exam, whereas 'Void' represents those who are abstaining from a particular AS. One of the quirks of the NCEA system is that a student does not need to pass every AS in order to pass or receive an endorsement in a particular subject. If a student feels that they might not pass a particular Ex AS they can choose to skip it and consequently receive a 'void' for that AS, which *does not* show on their record. If they start an Ex AS (i.e. attempt to answer some questions) but do not gain enough marks the student receives a 'Not Achieved', which *does* show on their record.

See figure 8: NCEA 3.6 pass rate for the years 2009 to 2013.

What stands out in Figure 8 is that about half the students sitting 3.6 are either failing or choosing to skip the electrical Ex AS. Furthermore, if we compare the pass rates of NCEA 3.6 with the other physics Ex AS, 3.3 waves and 3.4 mechanical systems, it is apparent that 3.6 has an unusually high void count. This is illustrated in Figure 49, which shows 22 per cent of students voided 3.6 Ex AS compared with only 7 per cent for Ex AS 3.3 and 3.4 during the 2013 exams. The results for other years are similar. This suggests that a significant number of students consider the electrical component of physics either too hard or not necessary.

See Figure 9: NCEA physics external achievement standard results 2013 (A) 3.6 electrical (B) 3.3 waves and 3.4 mechanical.

Secondary teachers' focus group findings

Following a few informal meetings and discussions with secondary school physics teachers, the EPECentre hosted its first outreach focus group workshop in February 2014. Teachers from five Christchurch-based secondary schools actively

participated at the workshop and provided their valuable perspectives. The following is a summary of findings from the first focus group workshop.

- » NCEA assessments in support of electrical engineering are based on outdated technology and need to be updated to suit modern environments that appeal to secondary students. For example, resources consisting of cathode ray television technology examples can be updated to refer to LED TV or smart phone technology.
- » Most schools teach electricity (NCEA 2.6 or 3.6) towards the end of the academic year to enable students to remember the content prior their external NCEA examinations. This is because NCEA 3.6 is usually considered to be the most difficult of the three external topics. However, there is often less time to teach it at the end of the academic year.
- » Students find concepts related to mechanics (NCEA 3.4) and waves (NCEA 3.4) easier to understand and therefore more exciting than electricity.
- » Most secondary schools are not equipped with sufficient resources, such as functioning oscilloscopes to run electrical circuit demonstrations and/or experiments.
- » Schools are in need of simple and reliable circuits that are easy to set up for classroom demonstrations and experiments. Teachers have 45 minutes available to them and circuits that often do not work during demonstrations can cause delays.
- » Students enjoy their outreach visits to UC laboratories and are likely to remember them for some time.



We are interested in the number of students opting to take physics in year 13. Moreover, we are particularly interested in the number of students who opt for the 'electrical systems' achievement standard (AS) in year 13."

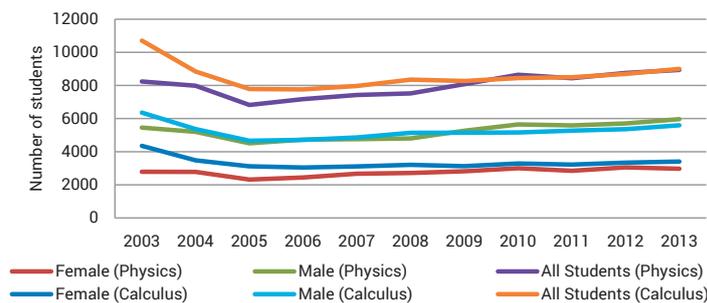
However, the theoretical aspects of UC demonstrations are not usually covered until the end of the year. UC staff's explanation of electrical systems may not be well understood by most students at the time of their visit. It also needs to be relevant to their 3.6 curriculum.

- » Secondary school physics teachers are interested in working together with the EPECentre, UC to develop resources and teacher refresher training programmes in support of NCEA 2.6 and 3.6.

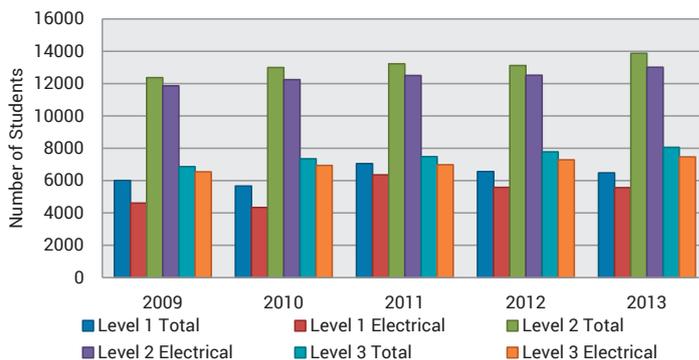
Points for discussion

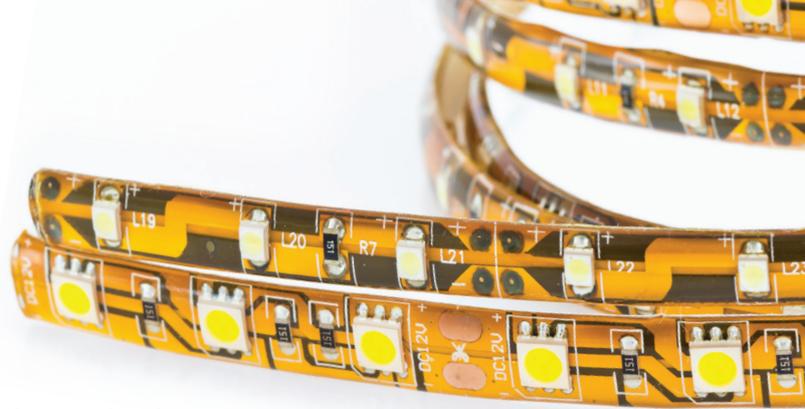
The survey results show students choosing engineering are primarily motivated by career prospects, with other lesser contributing factors, including family/friends, research activities and school teachers.

6: Year 13 physics and calculus, number of students enrolled in each course.



7: NCEA physics, number of students enrolled in external AS.





We invite secondary school teachers to contact us about our survey findings. Do you think there is a problem with Physics 3.6? Would you like to contribute to the field guide? What resources would help to deliver the 3.6 curriculum better?"

There is a noticeable difference between when students make up their minds to study EEE and other degree choices, such as mechatronics, with a significant portion of EEE students deciding in high school.

Furthermore, a significant number of EEE students were interested in the EEE programme over other disciplines, but this was not the case for mechatronics students, who appeared more interested in mechanical engineering.

One theory for this could be that EEE students already have a strong interest in electrical engineering despite other influencing factors, whereas mechatronics students who show some interest in electronics are turned away from electrical and towards mechanical due to a bad experience in high school.

While the drop in student numbers taking 'harder' NCEA courses such as calculus and physics is a concern for us, the bigger concern is the unusually high void rate for 3.6. The conversations we have had with secondary school physics teachers suggest there are significant problems with the curriculum for 3.6. This includes references to outdated technology and insufficient resources for teachers in the form of time and

equipment. We have looked at the curriculum and think it is too hard for a high school level. Some of the material we do not teach until second year university.

We believe there is a problem with NCEA Physics External Achievement Standard 3.6 and we are working to fix it. We are putting together a field guide to assist students and teachers with concepts of the 3.6 curriculum.

The guide, still in its early stages, contains videos explaining key concepts such as static electricity, DC electricity, electromagnetism and AC electricity; why they behave the way they do and how we have applied them to the world we live in. We plan to add more to the guide in the future, such as tutorials and games. Our longer-term goal is to look at getting a

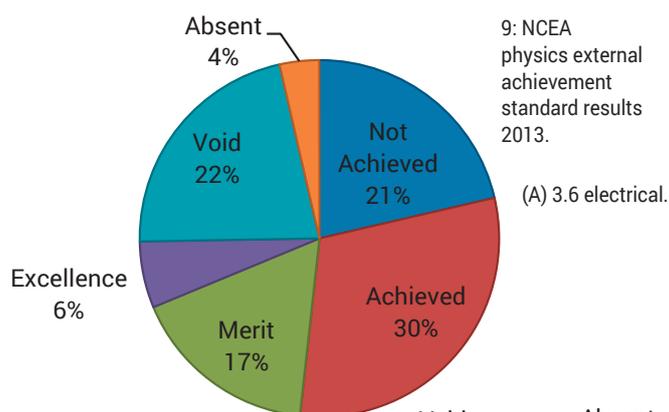
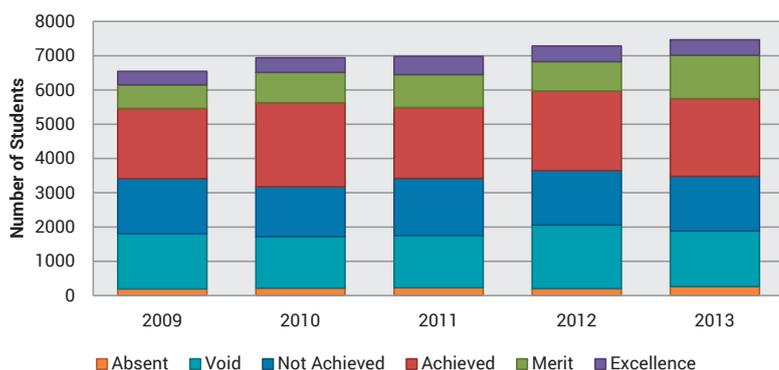
curriculum change around 3.6 to make it easier and more relevant to modern technology.

We invite secondary school teachers to contact us about our survey findings. Do you think there is a problem with Physics 3.6? Would you like to contribute to the field guide? What resources would help to deliver the 3.6 curriculum better? ↗

Acknowledgements

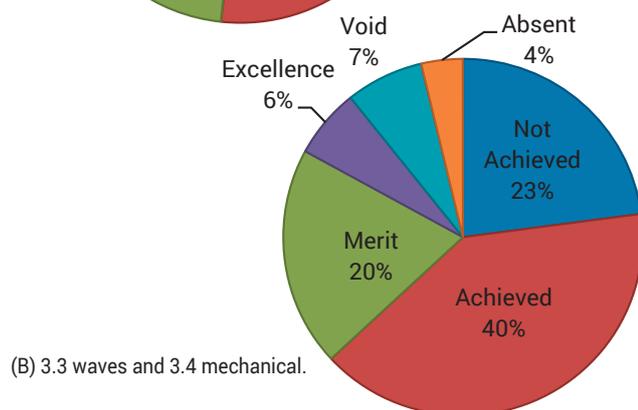
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8: NCEA 3.6 pass rate for the years 2009 to 2013.



9: NCEA physics external achievement standard results 2013.

(A) 3.6 electrical.



(B) 3.3 waves and 3.4 mechanical.