Briefing Note: Organisation for Economic Co-operation and Development (OECD) working paper, *The science of teaching science: an exploration of science teaching practices*

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<tr>
<th>To:</th>
<th>Hon. Chris Hipkins, Minister of Education</th>
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<tr>
<td>Date:</td>
<td>15 November 2018</td>
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<td>Priority:</td>
<td>Medium</td>
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<td>Draft:</td>
<td>Adam Jang-Jones</td>
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<td>Key contact and number:</td>
<td>Dr. Philip Stevens Round robin:</td>
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<td>Messaging seen by Communications team:</td>
<td>Yes</td>
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**Purpose of Report**

**Note:** the OECD will release a working paper, *The science of teaching science: an exploration of science teaching practices in PISA 2015* on **19 November 2018** (time to be confirmed) accompanied by a short PISA in Focus (PIF) insights paper.

**Agree:** that this briefing note is proactively released after the 21 November 2018.

**Summary**

- This working paper tells us New Zealand teachers are high users of all 5 science teaching practices examined in PISA 2015 and all but one are used in the context that they are best suited. The exception is inquiry-based science teaching.

- We have a high use of inquiry-based science teaching in low-SES schools and schools with poor disciplinary climates, where higher use is associated with lower science performance.

- All 5 science teaching practices examined in this report are positively associated with student attitudes, self-efficacy and career expectations related to science.

Craig Jones  
Deputy Secretary  
Evidence Data and Knowledge

Hon Chris Hipkins  
Minister of Education

5/11/18  
21/11/18
Background

1. A new OECD working paper, *The science of teaching science: an exploration of science teaching practices in PISA 2015* will be released on 19 November 2018 (Paris time to be confirmed). This paper explores the relationship between various science teaching practices and students' science-related outcomes.

2. It draws on data from the OECD's Programme for International Student Assessment (PISA) 2015. PISA 2015 data comes from a large representative random sample of 15-year-olds across 72 countries, including all (at the time) 35 OECD countries.

3. To assess science performance, PISA 2015 used 184 science test items of varying difficulty. Students also filled out a 40-minute background questionnaire, which included questions on their experiences of teaching practices, their enjoyment of and interest in science, and their expectations of a career in science. Nineteen countries (not including New Zealand) also gave teachers in PISA schools a teacher questionnaire, which also asked about their use of certain teaching practices.

4. The five science teaching practices below are examined in this paper. All of these teaching practices have varying degrees of potential to improve students' science outcomes and attitudes towards science.
   - Inquiry-based science teaching (IBST)\(^1\)
   - Teacher-directed science instruction (TDSI)
   - Adaptive instruction in science lessons (ATSL)
   - Teacher feedback in science lessons (TFSL)
   - Teacher support in science lessons (TSSL)

5. This paper examines teaching practices mainly from the point of view of students' experiences of these practices. It also draws at times on teacher questionnaire data.

6. A short PISA in Focus (PIF) insights paper (working title: *Do science teaching practices matter?*) will be released simultaneously to accompany this working paper.

Definitions

7. *Inquiry-based science teaching (IBST)* involves the teacher having limited control of the lesson and students exploring the processes of science for themselves.

8. *Adaptive instruction in science lessons (ATSL)* involves the teacher adapting their lessons following students' reactions to the lesson, primarily as a whole-class strategy (different from individualised instruction strategies).

9. *Teacher-directed science instruction (TDSI)* involves the science teacher providing explanations, demonstrations content, extension of content and discussion to direct what students learn.

10. *Teacher feedback in science lessons (TFSL)* involves the science teacher providing feedback to individual students on how to improve towards their learning goals.

11. *Teacher support in science lessons (TSSL)* involves the teacher being aware of students' progress and opinions, and helping students when needed.

12. Wording of the response options presented to students is listed in Annex 4.

\(^{1}\) This is called enquiry-based science teaching (EBST) in the OECD working paper. In New Zealand Inquiry-based is the more usual term.
13. Literature cited suggests that instructional practices have more impact on students' performance and attitudes than teacher experience or qualifications. It is therefore important to identify core teaching practices that have a positive impact on student outcomes.

**Inquiry-based science teaching (IBST)**

14. An 'index of IBST' was created based on the IBST questions asked of students. This shows New Zealand students experience IBST practices more frequently than on average across the OECD; however, many other OECD countries use these practices more frequently than New Zealand.

15. IBST is associated with lower scores for almost all countries in the PISA science assessment. This holds true across all PISA science competencies subscales, knowledge subscales and content area subscales. .

- In New Zealand, an increase of one unit on the IBST index is associated with students performing 14 points lower on the PISA science assessment (after accounting for student and school characteristics). 14 points is approximately equivalent to half a year of schooling. This is the second-highest negative association with performance among the PISA 2015 countries.

- Further analysis for New Zealand reveals that the IBST-performance relationship is not a straight linear relationship. It is only at the top end of highest IBST use (top quintile) that student science performance drops sharply.

16. The paper suggests that a possible explanation for the apparently negative effects of IBST on students' performance in science is that IBST is a demanding teaching strategy that requires specific resources and school climates. Supporting this hypothesis, across all countries students in science classes with a poor disciplinary climate perform worse in science when exposed to more frequent IBST activities.

17. Student-reported experiences of IBST are related to school factors, such as the average school socioeconomic status of students in a school (SES; advantaged schools - disadvantaged schools), school type (public - private) and school location (urban - rural).

- In some countries, IBST is more prevalent in disadvantaged schools (schools in the bottom 25% of socioeconomic status, SES), and in some it is more prevalent in advantaged schools (top 25% of SES).

- In New Zealand, IBST activities are statistically more common in socioeconomically disadvantaged schools (schools in the bottom 25% of SES) compared to advantaged schools, and more common in schools located in rural areas than in urban schools.

- In New Zealand, the use of IBST is high at all levels of school SES and has an especially high rate of IBST use in disadvantaged schools, compared to the use in disadvantaged schools in other countries. There is no statistical difference between New Zealand public and private schools in how often they use these practices.

18. In the countries where IBST is more prevalent in advantaged schools, its use is not statistically correlated with any change in student performance.

19. In New Zealand and across the OECD IBST is also associated with weakly-to-moderately higher student attitudes towards science. This holds true even after accounting for students' socioeconomic status (SES), gender, year level, science
performance and number of science subjects studied. Attitudes examined include:

- enjoyment of science, interest in broad science topics, science self-efficacy (self-belief in their ability to solve science problems or achieve science goals), science epistemic beliefs (valuing of scientific processes and approaches) and students' expectations of a science-related career at age 30.

- After controlling for student characteristics and school factors, New Zealand has the strongest relationship between higher IBST and student-reported enjoyment of science (although the strength of this relationship is still modest).

- New Zealand also has one of the strongest relationships between higher IBST and students' epistemic beliefs (that is, appreciation for the cumulative nature of scientific method). However, the strength of these relationships makes New Zealand not significantly different from the UK, Australia and Ireland. Unlike the OECD on average, there is no significant effect of IBST on the odds of a student expecting to pursue a science career.

**Teacher-directed science instruction (TDSI)**

20. TDSI is associated with slightly higher scores in the PISA science assessment. This holds true for almost all countries in PISA 2015. The same picture emerges across all PISA science competencies subscales, knowledge subscales and content area subscales.

- In New Zealand, an increase of one unit on the TDSI index is associated with students performing 7 points higher on the PISA science assessment (equivalent to about a quarter of a year of schooling), after controlling for student characteristics and school factors. This is the same as the OECD average (7 points).

21. For most countries, including New Zealand, when combined with Inquiry-based science teaching (IBST), the effect of TDSI is not strong enough to compensate for the negative effect of IBST. That is, an increased use of both methods is related to lower overall science performance.

22. TDSI is consistently related to higher science scores across all difficulty levels, all levels of student performance and all school contexts. TDSI appears to help students perform better on PISA questions of all difficulty levels, and this is similar across all PISA 2015 countries including New Zealand. TDSI is associated with stronger science performance at all levels of student performance (10th, 50th and 90th percentiles), and this is true across all PISA 2015 countries including New Zealand.

23. New Zealand has a high rate of TDSI (high on the PISA index of TDSI), as delineated by the questions PISA asked. This is similar to Australia and the United States.

- This can be explained in part by the inclusion in the index of questions about teachers leading 'whole-class discussions' and teachers 'discussing student questions', though these practices are uncommon in some countries due to very large class sizes and cultural expectations that students should not disrupt the class with their questions. One could argue that classes in such countries tend to be even more teacher-directed.

24. In most countries, students in advantaged schools (schools in the top quarter of socioeconomic status) and in private schools tend to report more frequent exposure to TDSI than students in disadvantaged schools and public schools.

- In New Zealand, while TDSI practices are statistically more common in private schools, there is no statistically significant difference between advantaged and disadvantaged schools in the use of these practices.
25. TDSI has a moderate to strong positive association to student enjoyment of science in most PISA 2015 countries. This relationship is ‘particularly strong’ in New Zealand. TDSI practices are also positively but weakly associated with students’ interest in broad science topics in New Zealand and most countries.
   - This suggests that students’ enjoyment and interest in science are not hindered by these teacher-directed methods.

26. Across the OECD, TDSI also shows weak-to-moderate positive relationships with students’ sense of self-efficacy in science, with students’ epistemic beliefs, and with the likelihood of students expecting a career in a science-related field.
   - After controlling for student characteristics and school factors, New Zealand has one of the strongest relationships between higher TDSI and student enjoyment of and interest in science (although the strength of these relationships is still modest (enjoyment) or weak (interest)).
   - The use of TDSI in New Zealand also has a weak positive relationship (but above OECD average) to student-reported self-efficacy in science, student epistemic beliefs and, unlike IBST, also the likelihood of expecting a science-related career.

27. Overall, TDSI is a ‘robust teaching practice’, reliably associated with higher student performance in science regardless of school context.

**Adaptive instruction in science lessons (ATSL)**

28. ATSL is associated with slightly higher student scores in the PISA science assessment. This holds true for the majority of countries in PISA 2015. The same picture emerges across all PISA science competencies subscales, knowledge subscales and content area subscales. The paper hypothesises that this is because adapting the lesson helps ensure that students are understanding well.
   - In New Zealand, an increase of one unit on the ATSL index is associated with students performing 7 points higher on the PISA science assessment, after controlling for student characteristics and school factors. This is the same as the OECD average (7 points).

29. New Zealand students experience among the highest rates of ATSL in the OECD (high on the PISA index of ATSL), similar to Canada, Australia and the United States. ATSL is used at similar levels across all school SES levels in New Zealand. In New Zealand, there is no statistical difference between public and private, or urban and rural schools in their frequency of use of ATSL.

30. ATSL tends to be more frequently used in education systems with higher rates of ability grouping within classes and in systems where residence in particular area is regularly considered for school admissions. By contrast, ATSL tends to be less common in education systems with higher rates of ability grouping between classes and between-school grouping of students into different educational tracks.

31. On average across the OECD, ATSL is most common in small schools (with fewer than 100 students enrolled). This may be because the teachers in small schools have more interactions with the students and better understanding their needs and level of previous learning.

32. ATSL is also more common, on average across the OECD, in schools with a positive disciplinary climate and in schools with higher proportions of disadvantaged students.

33. ATSL has a moderate to strong association to student enjoyment of science in nearly all PISA 2015 countries. Compared to the other OECD countries, New Zealand has one of the strongest relationships between ATSL and enjoyment.
34. ATSL practices are weakly associated with higher epistemic beliefs in all countries. In the majority of countries, ATSL is also moderately-to-weekly related to a higher likelihood of a student expecting a career in a science-related field. Again, New Zealand is above the OECD average for the strength of these relationships.

**Teacher feedback in science lessons (TFSL)**

35. TFSL is associated with lower student scores in the PISA science assessment. This holds true for almost every country in PISA 2015. The same picture emerges across all PISA science competencies subscales, knowledge subscales and content area subscales.

- In New Zealand, an increase of one unit on the TFSL index is associated with students performing 12 points lower on the PISA science assessment, after controlling for student characteristics and school factors. New Zealand has among the greatest difference in performance associated with TFSL, along with Iceland, Finland and Korea, and significantly above the OECD average (–7 points).

- Rather than individualised feedback on performance having a negative effect on student achievement, the students who are getting the most frequent teacher feedback on how to improve are struggling students who are performing significantly below their peers. Such students would likely perform worse if the teacher didn’t give this feedback.

- In New Zealand after adjusting for student and school characteristics, there is still a negative relationship between these types of feedback and student performance. This may imply that for all levels of students, not just low-achieving ones, those who receive the most feedback are those who are performing less well compared to their counterparts in similar situations.

36. New Zealand students experience among the highest rates of TFSL in the OECD (high on the PISA index of TFSL), alongside the United States but below Mexico and the UK. TFSL is used more frequently in the lower school SES levels in New Zealand, though this difference isn’t as high as in many OECD countries. Relative to other OECD countries, TFSL appears relatively common in all SES levels of New Zealand schools. In New Zealand, there is no statistical difference between public and private, or urban and rural schools in their frequency of use of TFSL.

- This can be explained in part by these practices of individualised feedback being uncommon in some countries due to very large class sizes and cultural expectations that teachers shouldn’t give feedback individually.

- Compared to other OECD countries, New Zealand students report nearly the highest rate of their teacher "tells me in which areas I can still improve" in every or most lessons.

37. In almost all PISA 2015 countries, boys report more frequent teacher feedback than girls. Compared to the OECD average, New Zealand has lower gender differences in teacher use of feedback.

38. TFSL has a moderate to strong association to student enjoyment of science in nearly all PISA 2015 countries. Compared to the other OECD countries, New Zealand has one of the strongest relationships between TFSL and enjoyment.

39. In most countries TFSL is also moderately associated with higher interest in science, with New Zealand near the OECD average. TFSL is weakly related to students’ epistemic beliefs and self-efficacy in science in most countries, with New Zealand slightly above the OECD average, and is also moderately-to-weekly related to a higher
likelihood of a student expecting a career in a science-related field (New Zealand is the same as the OECD average).

Teacher support in science lessons (TSSL)

40. TSSL is associated with slightly higher student scores in the PISA science assessment for about half the countries in PISA 2015, and is associated with slightly lower scores for another 4 countries. However, the association is, on average, weak. In New Zealand, TSSL appears to have no association with performance.

41. On average across the OECD, an increase in exposure in TSSL is associated with moderately more positive attitudes towards science. There is no breakdown of figures for New Zealand on these measures.

Comment

42. The report suggests all of these teaching practices are, in the right school and student context, related to improved student performance. However, caution is strongly advised on the overuse of inquiry-based instruction, particularly without strong teacher subject expertise. All of them are effective for improving students’ attitudes towards science and science-related careers.

43. These findings will be of most interest to science teachers, ITE and PLD providers, as well as policy makers with influence in science teaching.

44. These findings will be presented at the New Zealand Association for Research in Education (NZARE) annual conference on 26 November by the Ministry’s PISA 2018 National Project Manager, Adam Jang-Jones.

Next steps

45. This PIF and OECD working paper may receive media attention in New Zealand.

46. We will work closely with your Office on these materials.
Annexes

Annex 1: Final draft of OECD working paper: “The science of teaching science: an exploration of science teaching practices in PISA 2015”.

IMPORTANT NOTE: This draft is permanently embargoed.

This working paper is copyrighted to the OECD. It may not be published or distributed to other persons.

The final published report will be available from

www.oecd-ilibrary.org/education

The final content of this paper may change. Please do not cite. Please check against final published report when available.

Annex 2: Final draft of PISA in Focus 89: “Do science teaching practices matter?”

IMPORTANT NOTE: This draft is permanently embargoed.

This paper is copyrighted to the OECD. It may not be published or distributed to other persons.

The final published report will be available from

www.oecd-ilibrary.org/education/pisa-in-focus_22260919
Annex 3: Summary of changes in student performance and attitudes related to science teaching practices

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<th>Science teaching practice</th>
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<td></td>
<td>NZ</td>
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Statistically significant findings are shown in **bold** text.

*Change associated with a 1-unit increase in the index of the teaching practice (accounting for student and school factors).
Annex 4: Wording of the questions

Inquiry-based science teaching (IBST) questions asked students how often the following activities occur when learning science at school.

- Students are given opportunities to explain their ideas.
- Students spend time in the laboratory doing practical experiments.
- Students are required to argue about science questions.
- Students are asked to draw conclusions from an experiment they have conducted.
- The teacher explains how a science idea can be applied to a number of different phenomena (e.g. the movement of objects, substances with similar properties).
- Students are allowed to design their own experiments.
- There is a class debate about investigations.
- The teacher clearly explains the relevance of <broad science> concepts to our lives.
- Students are asked to do an investigation to test ideas.

(Response options: In all lessons, In most lessons, In some lessons, Never or hardly ever.)

Teacher-directed science instruction (TDSI) questions asked students how often the following teacher behaviours occur when learning science at school.

- The teacher explains scientific ideas.
- A whole class discussion takes place with the teacher.
- The teacher discusses our questions.
- The teacher demonstrates an idea.

(Response options: Never or almost never, Some lessons, Many lessons, Every lesson or almost every lesson.)

Adaptive instruction in science lessons (ATSL) questions asked students how often the following teacher behaviours occur when learning science at school.

- The teacher adapts the lesson to my class’s needs and knowledge.
- The teacher provides individual help when a student has difficulties understanding a topic or task.
- The teacher changes the structure of the lesson on a topic that most students find difficult to understand.

(Response options: Never or almost never, Some lessons, Many lessons, Every lesson or almost every lesson.)
Teacher feedback in science lessons (TFSL) questions asked students how often the following teacher behaviours occur when learning science at school.

- The teacher tells me how I am performing in this course.
- The teacher gives me feedback on my strengths in this science subject.
- The teacher tells me in which areas I can still improve.
- The teacher tells me how I can improve my performance.
- The teacher advises me on how to reach my learning goals.

(Response options: Never or almost never, Some lessons, Many lessons, Every lesson or almost every lesson.)

Teacher support in science lessons (TSSL) questions asked students how often the following teacher behaviours occur when learning science at school.

- The teacher shows an interest in every student's learning.
- The teacher gives extra help when students need it.
- The teacher helps students with their learning.
- The teacher continues teaching until the students understand.
- The teacher gives students an opportunity to express opinions.

(Response options: Every lesson, Most lessons, Some lessons, Never or hardly ever.)