Singapore and PISA

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TRANSFORMING TEACHING
INSPIRING LEARNING

An Institute of NANYANG TECHNOLOGICAL UNIVERSITY

PISA 2015 Science Literacy Framework

- Contexts
- Knowledge
- Attitudes
- Competencies

Singapore's Performance in PISA (Science)

- Above-average Science performance
- Stronger than average epistemic beliefs
- Above-average percentage of students expecting to work in a Science-related occupation

Singapore students excel in all aspects of science assessed

Overall Mean Performance (MP) in Science = 556		
Competencies	Knowledge	Content
Explain phenomena scientifically (553)	Content (553)	Physical Systems (555)
Evaluate and design scientific inquiry* (560)	Procedural* (558)	Living Systems* (558)
Interpret data and evidence scientifically (556)	Epistemic* (558)	Earth and Space Systems (554)
OECD Average = 493		

Note: Values in parentheses are corresponding mean scores. *Strength Areas (OECD, 2016)

Explaining Singapore's Success in PISA-Science

MOE Policy

- MOE's vision and mission
- School improvement policy
- Centralised and evolving curriculum
- Investment in school resources and educational research

Levers of Educational Success and Reforms

- Unity in purpose
- Strong alignment and coordination
- Systematic and coherent implementation
- Strong adaptability of relatively young teaching force

Teacher training

- Stringent selection of student teachers
- Continuous professional development
- Schools
  - Highly informed school teachers
  - Well-resourced science department
- Classrooms
  - Adaptive / pragmatic science instruction
  - Highly motivated students

The Role of NIE

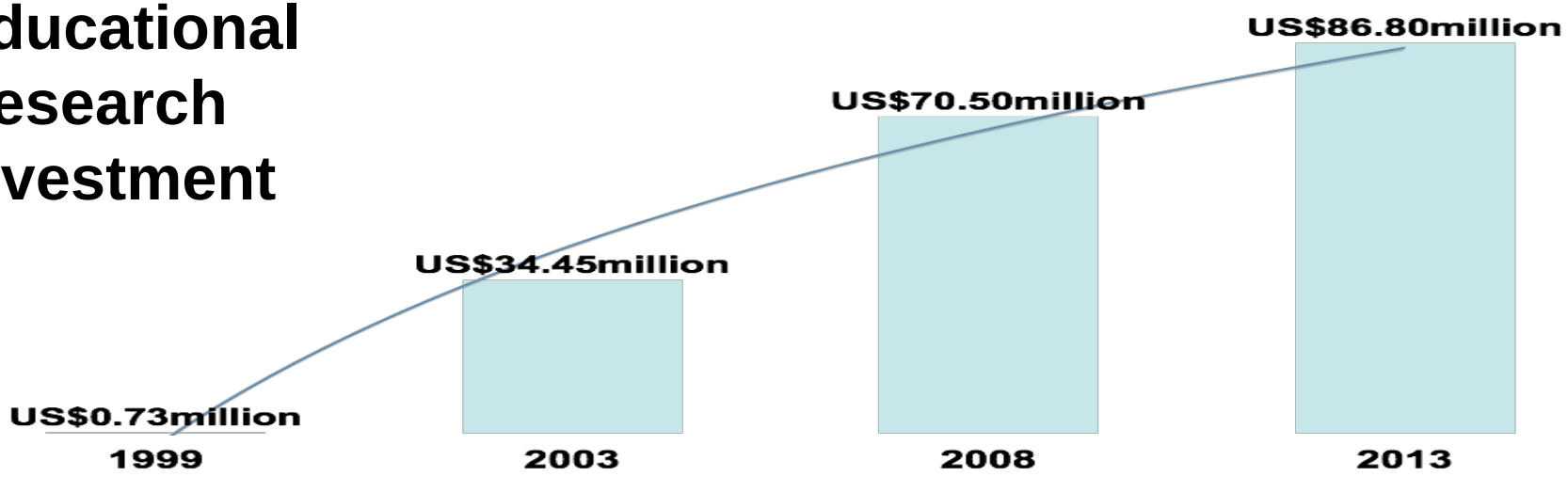
- Ensure current and research-informed science content is taught to pre-service teachers
- Authentic scientific research for pre-service teachers
- Conduct educational research together with schools
- Involved in national science curriculum development

How NIE differs from other systems

- Scientists and educators work together to ensure content accuracy and currency
- Close dialectical relationship with Curriculum Planning and Development Division (MOE) and Academy of Singapore Teachers ensures that research and teaching at NIE is aligned at the national level

Strong government support for education

Educational Research Investment



MOE to NIE in 1999 in the form of the Education Research Fund (EdRF), with an annual budget of SGD $1 million (US $730K). This initiative was in response to the Thinking Schools, Learning Nation policy of 1997 (Gopinathan & Hung, 2010).

MOE decision to establish NIE as a research-intensive Institute focused on generating primary research findings from the local context to inform education policy and practice in Singapore, the Ministry of Education - in January 2003 - announced the award of SGD $47.29 million (US$34.45 million) to NIE to establish the Centre for Research in Pedagogy and Practice (CRPP).

MOE responded with a substantial grant of SGD $96.6 million (US$70.5 million). The Office of Education Research (OER) was set up in April 2008 to chart directions for NIE education research, manage and ensure the qualities of education research projects, and to enhance the linkage between NIE researchers, school practitioners and MOE policy makers.

In 2013, a third grant of SGD $ 118 million was provided by the Ministry to sustain and enhance NIE's Education Research Funding Programme (ERFP).

(Hung, Tan & Kwek, 2017)

Strong educational vision

- Vision of the Ministry of Education

  “Thinking Schools, Learning Nation” (TSLN)

  This vision describes a nation of thinking and committed citizens capable of meeting future challenges, and an education system geared to the needs of the 21st century.

Strong educational mission

- Mission of the Ministry of Education

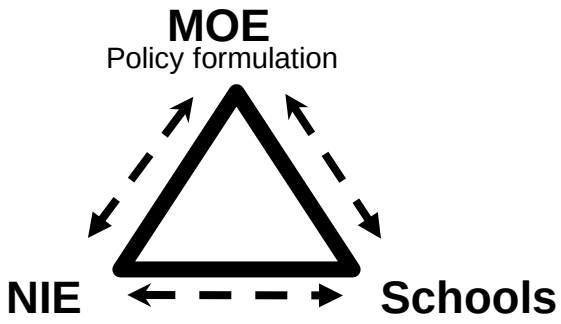
  To mould the future of the nation by moulding the people who will determine the future of the nation.

  MOE will provide our children with a balanced and well-rounded education, develop them to their full potential, and nurture them into good citizens, conscious of their responsibilities to family, community and country.

Systemic approach for implementing reforms

Design & delivery of teacher education programme

Providing research evidence to help shape future policies



Provide spaces for research and teaching experience

Grow beginning teachers to become professionals

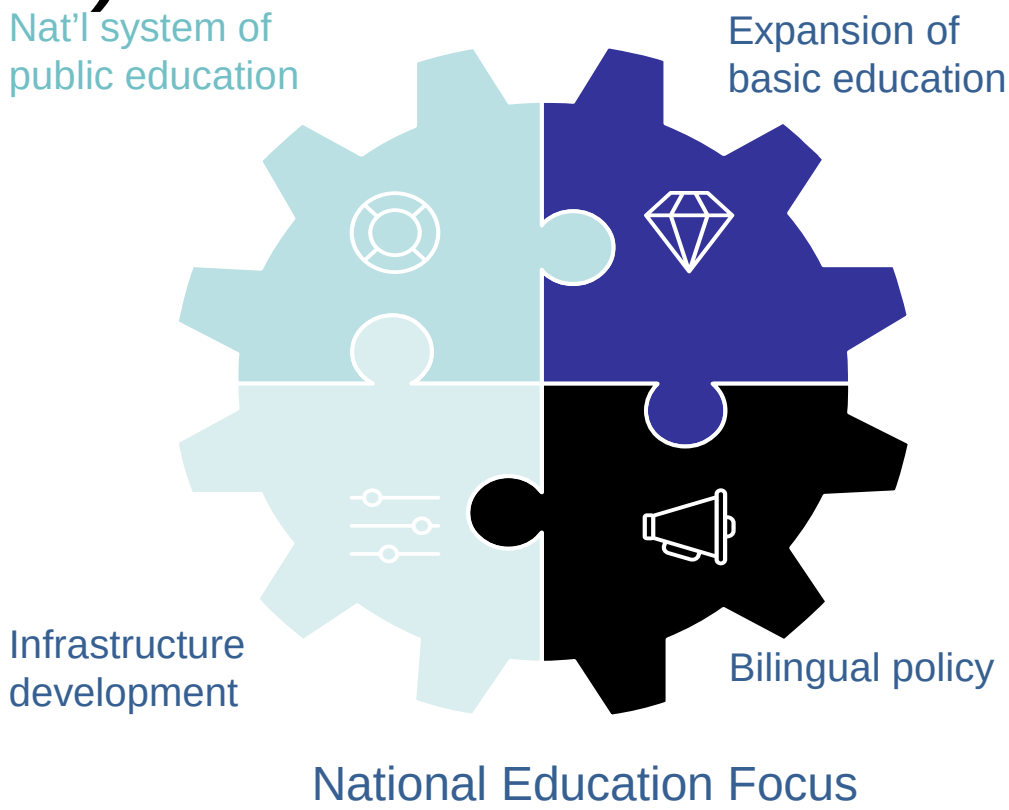
A key success factor for Singapore's high performance in international education benchmarks is the close **partnership** and **alignment** between **NIE, MOE** and schools in **Singapore**.

(Hung, Tan & Kwek, 2017)

Science Education during Survival-Driven Phase (1959-1978)

Key Initiatives

- Inclusion of science in primary school curriculum (1959)
- Gradual switch of medium of instruction from English and the vernacular to English only (1978)
- Availability of specialised training in science teaching through the Institute of Education
- Popularizing science learning through Science Fair, Quiz Bee, and Science Centre

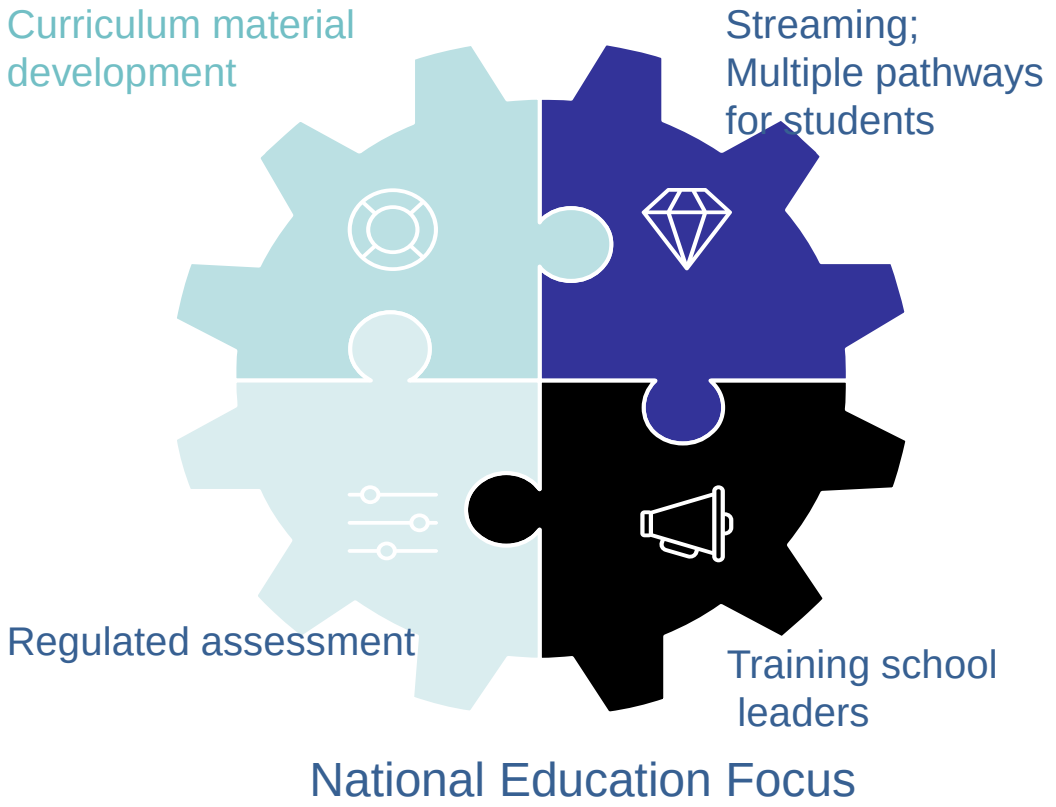


(Boon & Gopinathan, 2008; OECD, 2010; Poon, 2014)

Science Education during Efficiency-Driven Phase (1979-1996)

Key Initiatives

- Introduction of Science in Primary 3
- Teacher proofing of curriculum through local production of textbooks and teaching guides
- Setting up of science garden (primary) and science laboratories (secondary) in schools
- Greater curriculum time allotment for laboratory-based activities
- Inclusion of science practical tests in national exams
- Engagement of students in non-formal science activities

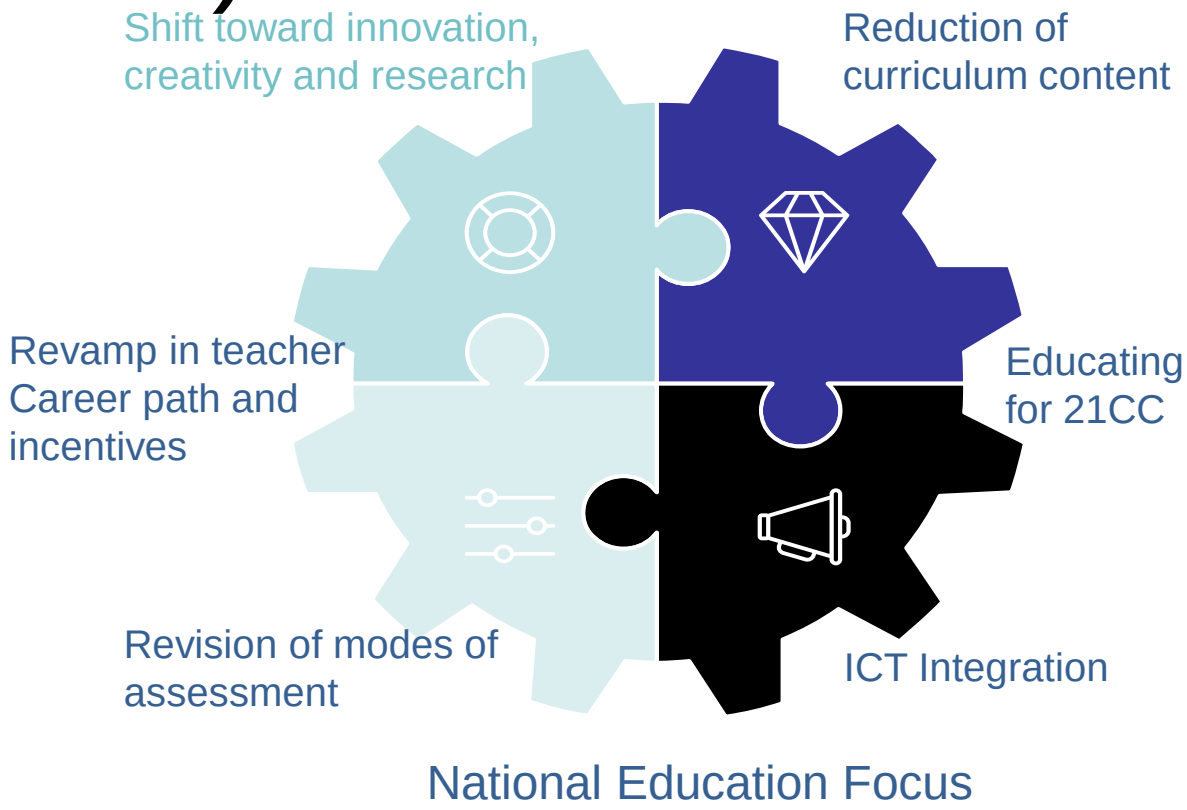


(Boon & Gopinathan, 2008; OECD, 2010; Poon, 2014)

Science Education during Ability-Driven Phase (1997-2011)

Key Initiatives

- Revision of science syllabi
- Integration of new developments in computing technology, telecommunications, biotech, nanotech, and clean energy
- Emphasis on hands-on and more open-ended investigations
- Establishment of specialised schools
- Additional resources for science teaching/learning
- Introduction of school-based science practical assessment

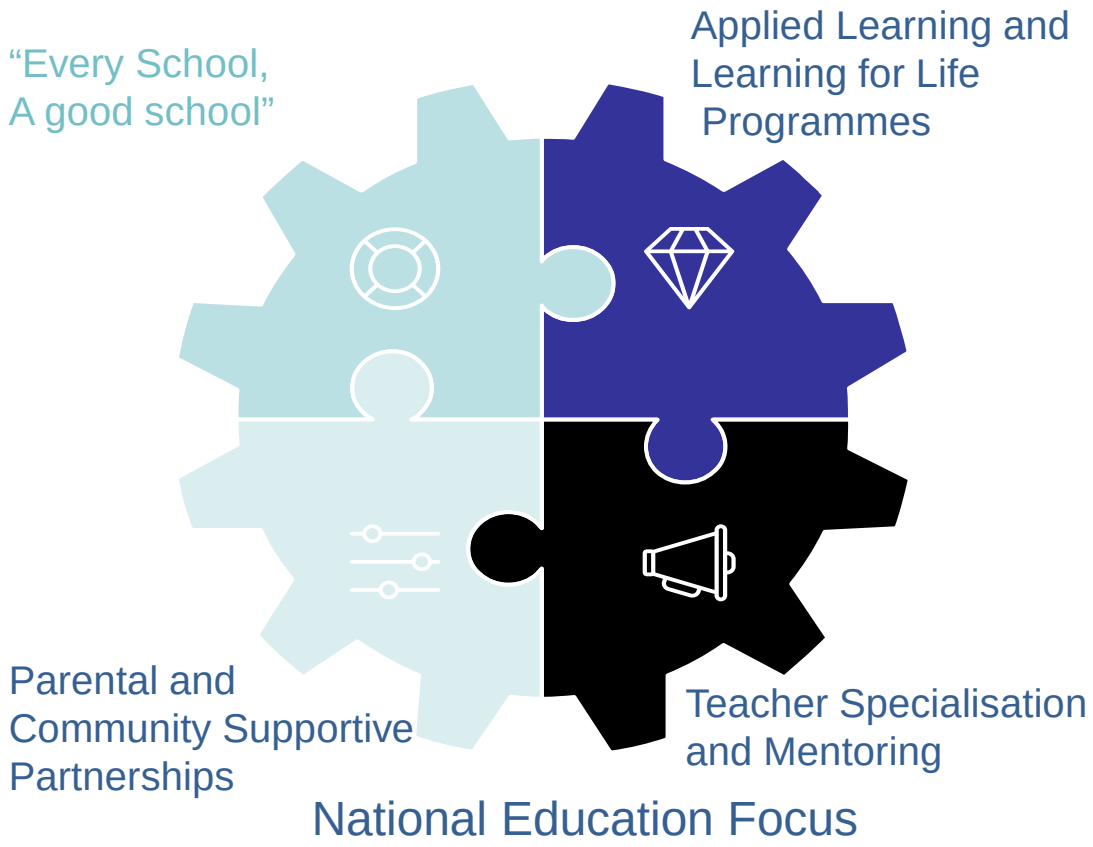


(Boon & Gopinathan, 2008; OECD, 2010; Poon, 2014)

Science Education during Student-Centric, Values-Driven Phase (2011-present)

Key Initiatives

- Emphasis on authentic and practice-oriented learning
- Bridging academic knowledge to work settings
- Inclusion of 21st century competencies in revised curriculum
- Implementation of the Applied Learning Programme (ALP)
- Broadening partnership with industry, community, institutions of higher learning, and/or professional training bodies

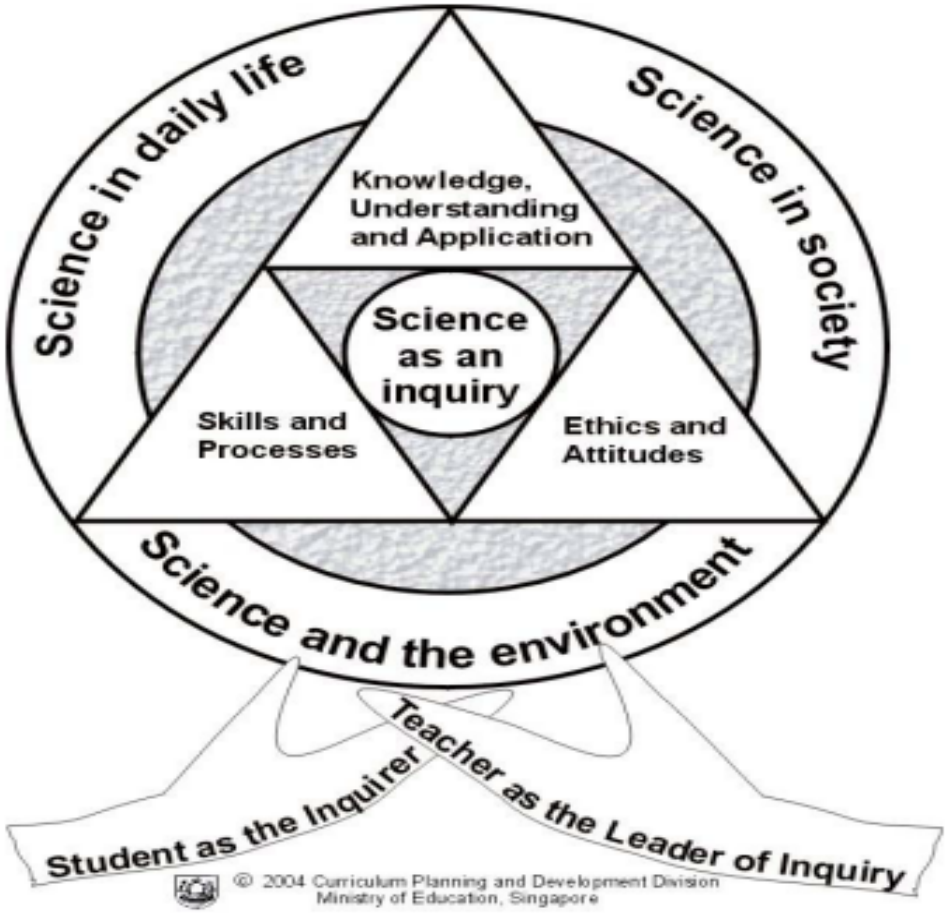


(Meng, 2014; Keat, 2015; MOE, 2017)

Critical Levers of Education Success as Reflected in the History of Science Education

- Evolving curriculum
- Strong support for professional development of teachers and school leader
- Tight alignment of curriculum, pedagogy, and assessment
- Growing investment in material resources (e.g., standardised curriculum materials, well-equipped classrooms and laboratories)

Science Curriculum Framework (MOE, 2012)



Lower Secondary Science Syllabus

- Diversity
- Models
- Systems
- Interactions

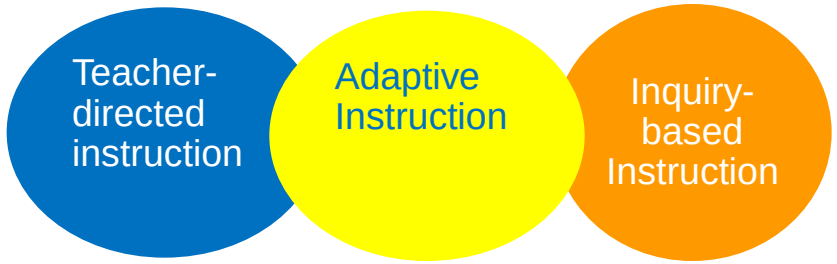
Strengths of the Singapore Science Curriculum

- Frame learning science as inquiry beginning from Grade 3
- Strong focus on conceptual knowledge and understanding
- Emphasis on learning and mastery of cognitive learning outcomes
- Integration of emphasis on values and attitudes
- High demands through breath of knowledge
- High fidelity of enactment of curriculum materials

[Lee, Kim and Yoon et al., 2015; Hollins & Reiss, 2016; Lin, Tan and Tsai, 2013]

Teaching of Science

- Teaching not only covers the types of strategies that teachers use, but also the time allocation for each type of strategy to be used and the content to be learned.
- In PISA 2015, students' reports were utilize to examine teachers utilization of three key science teaching strategies.



Teacher-directed Instruction

(Simmons, et al., 1999; OECD, 2016)

- The teacher serves as the primary source of most of the content knowledge to be transmitted to students (Simmons, et al., 1999; OECD, 2016)/
- The teacher takes the key responsibility to organize and impart content knowledge to students (Simmons, et al., 1999; OECD, 2016)The teacher serves as the sage of the stage.
- The teaching style focuses on teacher providing explanation, whole-class discussion and demonstration of science principles to students (Simmons, et al., 1999; OECD, 2016)
- Teacher-directed instruction, which is directed towards content mastery and examination preparation, is correlated to (OECD, 2016) and is predictive of student academic achievement (Hogan, 2014).

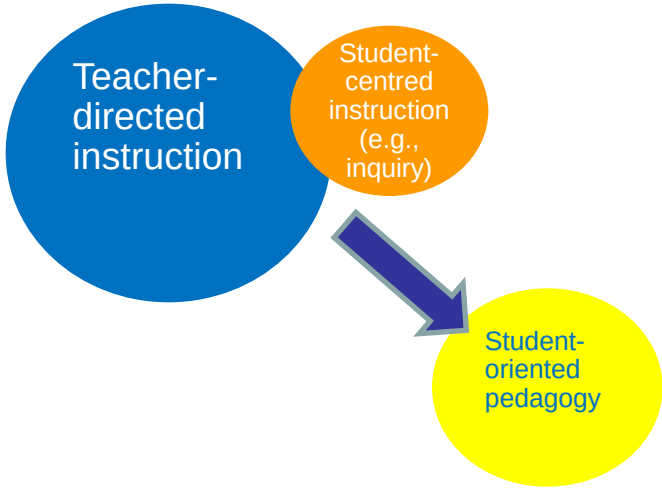
Adaptive Instruction

- *Adaptive instruction* offers flexibility to teachers in tailoring their teaching approach according to students' needs, knowledge and ability (Hofstein & Lunetta, 2004)
- Characteristic activities of adaptive instruction : (1) teachers' provision of support to students struggling academically; (2)modification of lesson structure for topics that are challenging for students, and (3) tailoring of lessons according to the students' knowledge and needs (OECD, 2016).
- Adaptive instruction is positively correlated with students' academic achievement and epistemic beliefs (OECD, 2016).

Inquiry-based instruction

- Inquiry refers to the way in which scientist study the natural world, propose ideas, explain and justify assertions based on evidence (Hofstein, & Lunetta, 2004)
- Characterized by the following activities: (1) designing and carrying out experiments; (2) presenting findings; (3) drawing conclusions from experimental evidence; (4) students explain and argue about their ideas; and (5) teachers linking scientific ideas to real-life settings and daily life (OECD, 2016).
- Adaptive instruction is negatively correlated with students' academic achievement and positively correlated with students' epistemic beliefs (OECD, 2016).

Nature of Pedagogy in Singapore Classrooms



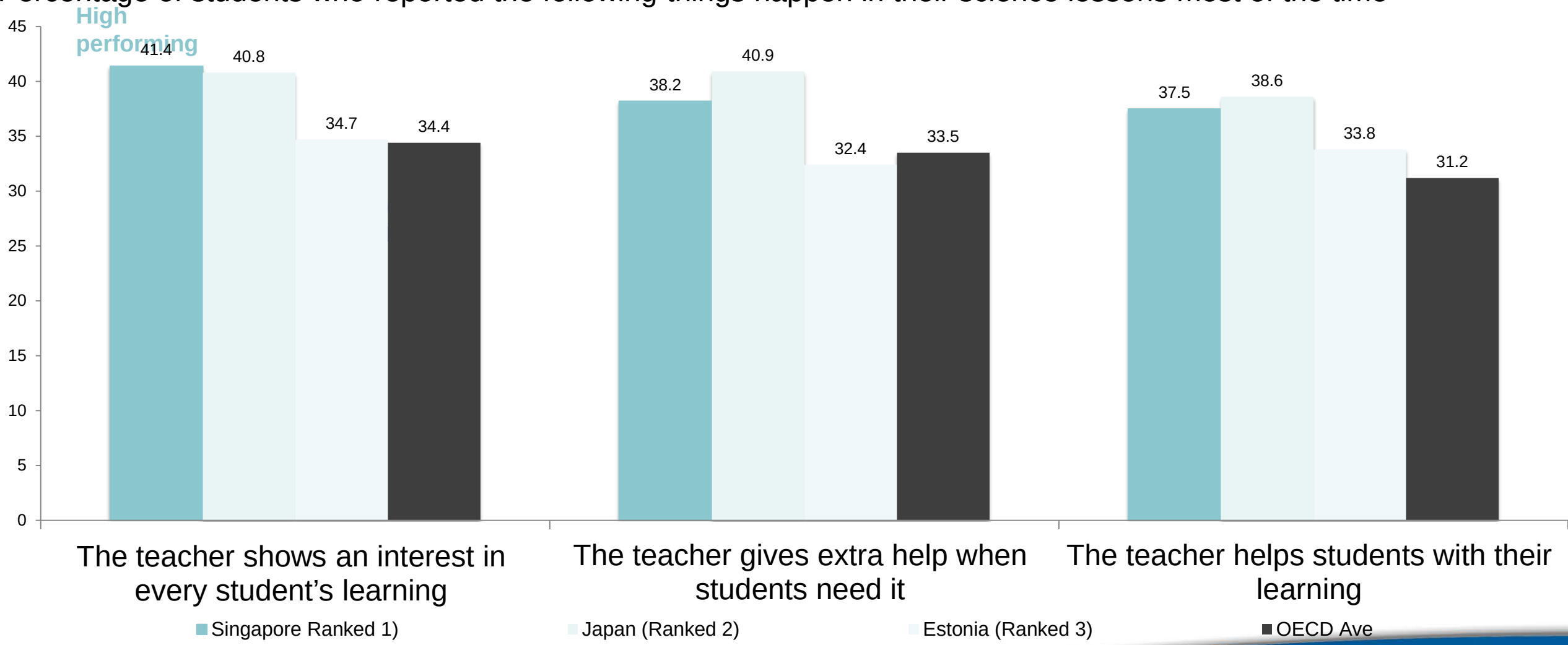
Student-oriented Pedagogy

(Caleon, Tan & Cho, 2016)

- Teachers acknowledge and respect the differences among learners in terms of backgrounds, interests, abilities, difficulties, and needs.
- Teachers modify their teaching strategies according to their perceptions of students' process of learning, ability to learn, and learning needs; strategies are implemented in teacher-directed manner
- Teacher remains as the *sage of the stage* (i.e., instruction remains teacher-dominated with less input from and control of students)
- It serves as a step away from teacher-directed and a step closer to student-centred pedagogy

Student-oriented Pedagogy:
Students feel that their teachers are supportive and go the extra mile.

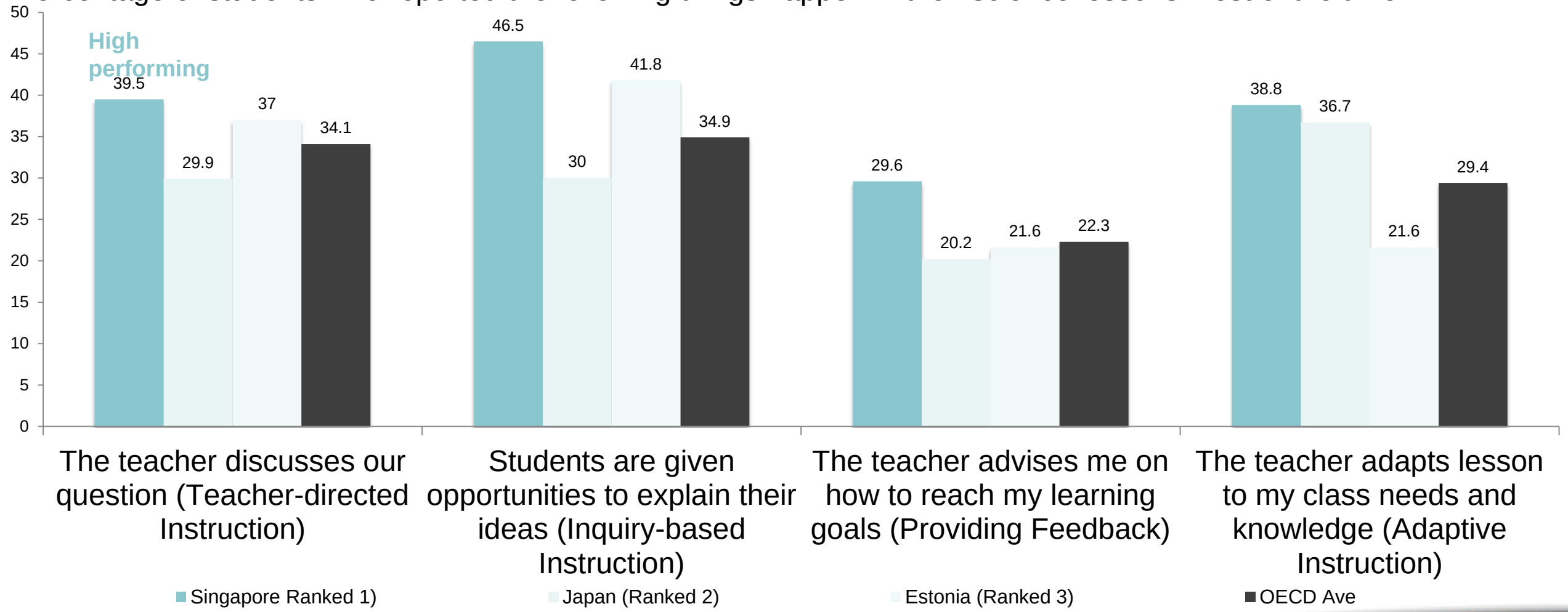
Percentage of students who reported the following things happen in their science lessons most of the time



OECD, 2016

Student-oriented pedagogy contributes to Singapore students' strong performance

Percentage of students who reported the following things happen in their science lessons most of the time



OECD, 2016

Teachers as Key in Implementing an Evolving Curriculum

- Policy and reform initiatives are implemented and sustained with high fidelity by a highly qualified teaching force
- Teachers use a pragmatic pedagogy (i.e., adaptive instruction and hybrid approaches that are largely teacher-directed) and thus can respond effectively to an evolving curriculum

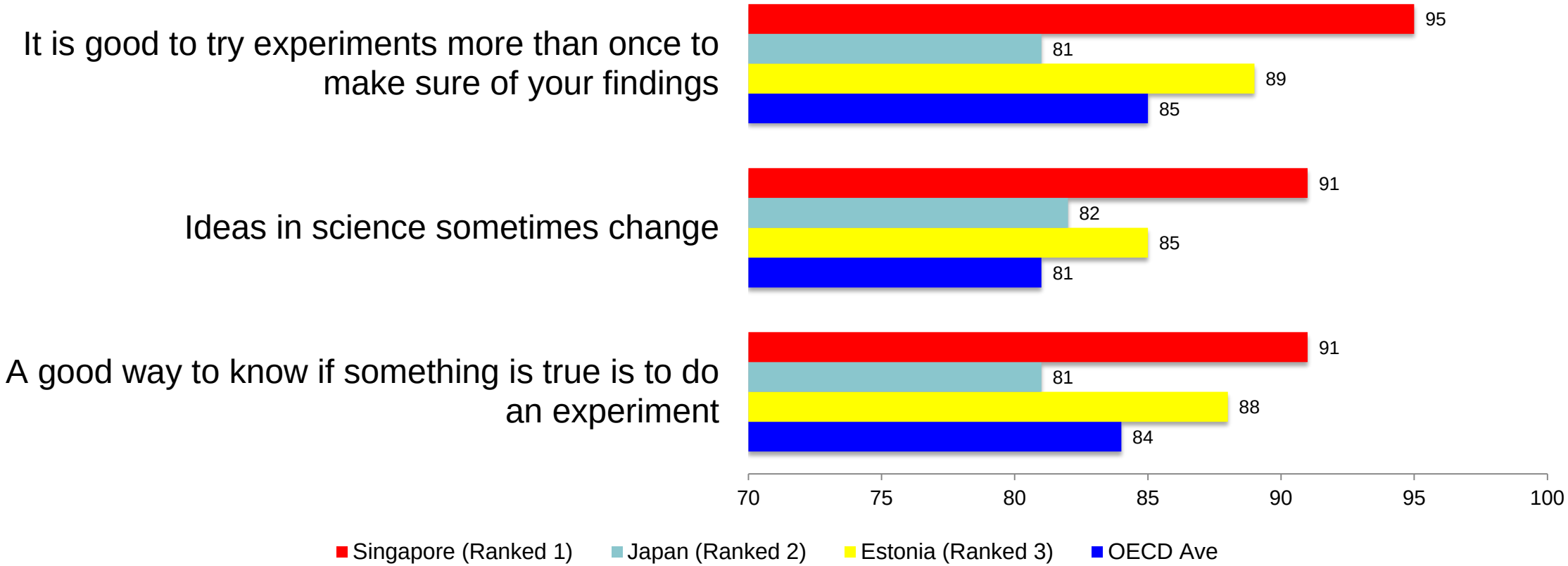
Snapshot of Students' Science Beliefs, Engagement and Motivation

Index of epistemic beliefs	• Singapore mean index is 0.22 • Higher than the mean index of OECD average at 0.00
Share of students with science-related career expectations	• Singapore share is 28.0% of all students • Higher than the OECD average of 24.5%
Index of enjoyment of learning science	• Singapore mean index is 0.59 • Higher than the man index of OECD average at 0.02

[Source: OECD, 2016, Figure I.1.s, p. 45l]

Singapore students have high constructivist epistemic beliefs

Percentage of students who agreed or strongly agreed with the following statements

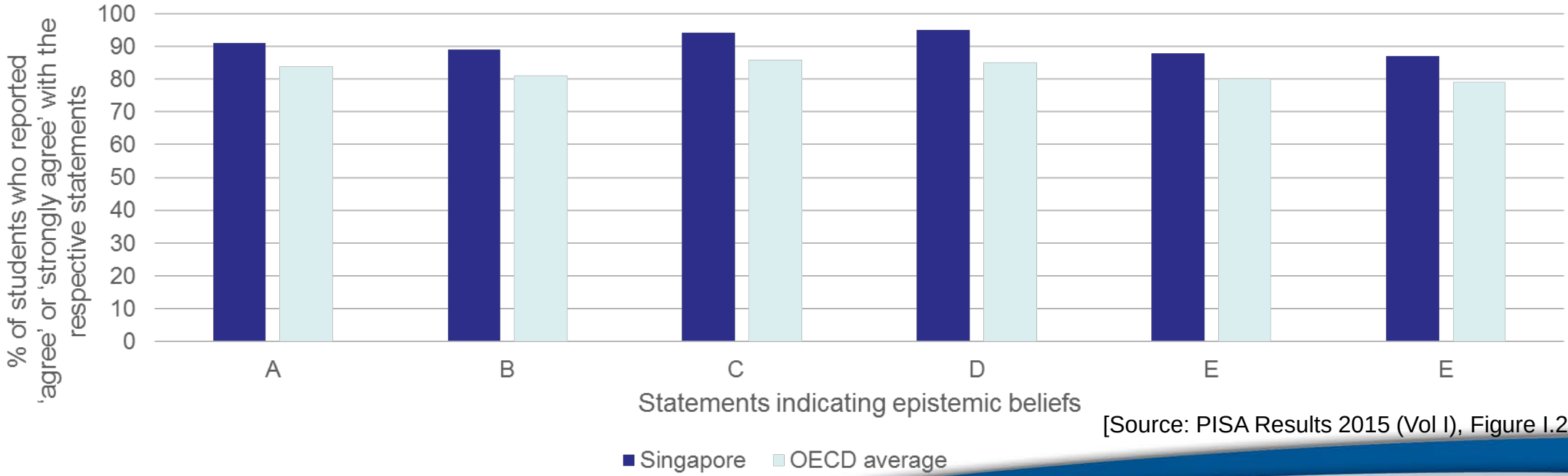


Having high constructivist beliefs suggests that Singapore students **greatly value scientific approaches to inquiry** and **understand the nature of science knowledge**.

OECD, 2016

Singapore students' epistemic beliefs about science

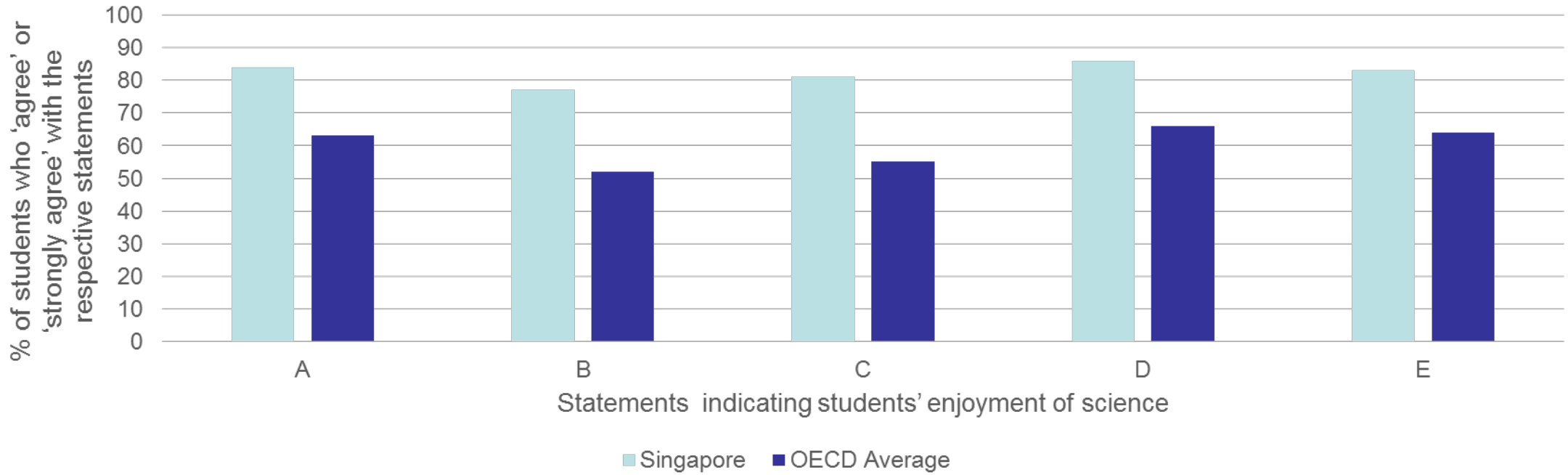
A	A good way to know if something is true is to do an experiment
B	Ideas in <broad science> sometimes change
C	Good answers are based on evidence from many different experiments
D	It is good to try experiments more than once to make sure of your findings
E	Sometimes <broad science> scientists change their minds about what is true in science
F	The ideas in <broad science> science books sometimes change



[Source: PISA Results 2015 (Vol I), Figure I.2.32, p. 101]

Students' enjoyment of science

A	I generally have fun when I am learning
B	I like reading about <broad science>
C	I am happy working on <broad science> topics
D	I enjoy acquiring new knowledge in <broad science>
E	I am interested in learning about <broad science>



[Source: PISA Results 2015 (Vol I), Figure I.3.9, p. 122]

Students' instrumental motivation to learn science

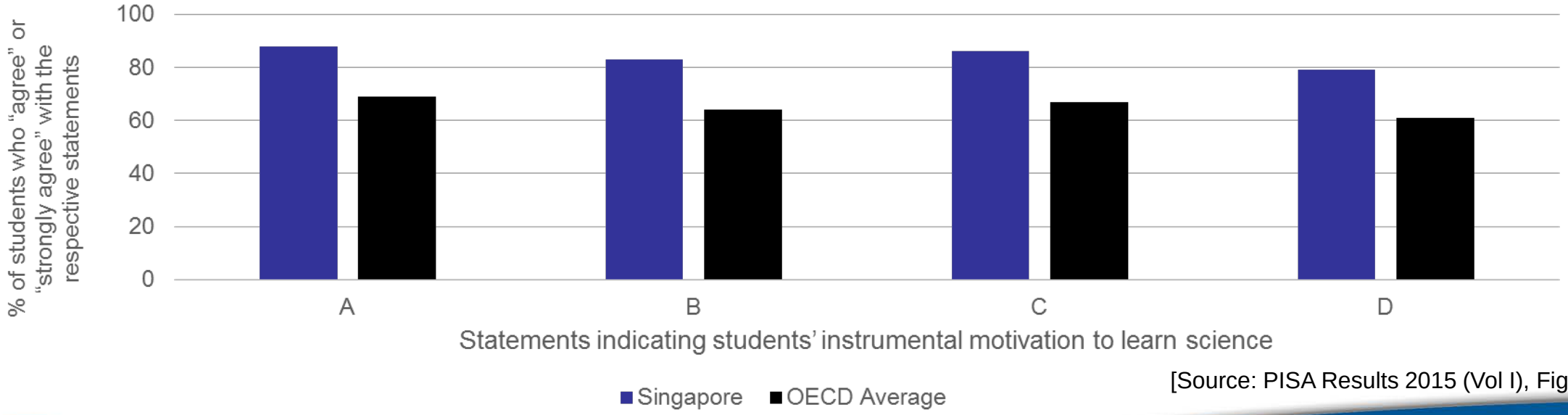
A Making an effort in my <school science> subject(s) is worth it because this will help me in the work I want to do later on

B What I learn in my <school science> subject(s) is important for me because I need this for what I want to do later on

C Studying my <school science> subject(s) is worthwhile for me because what I learn will improve my career prospects

D I enjoy acquiring new knowledge in <broad science>

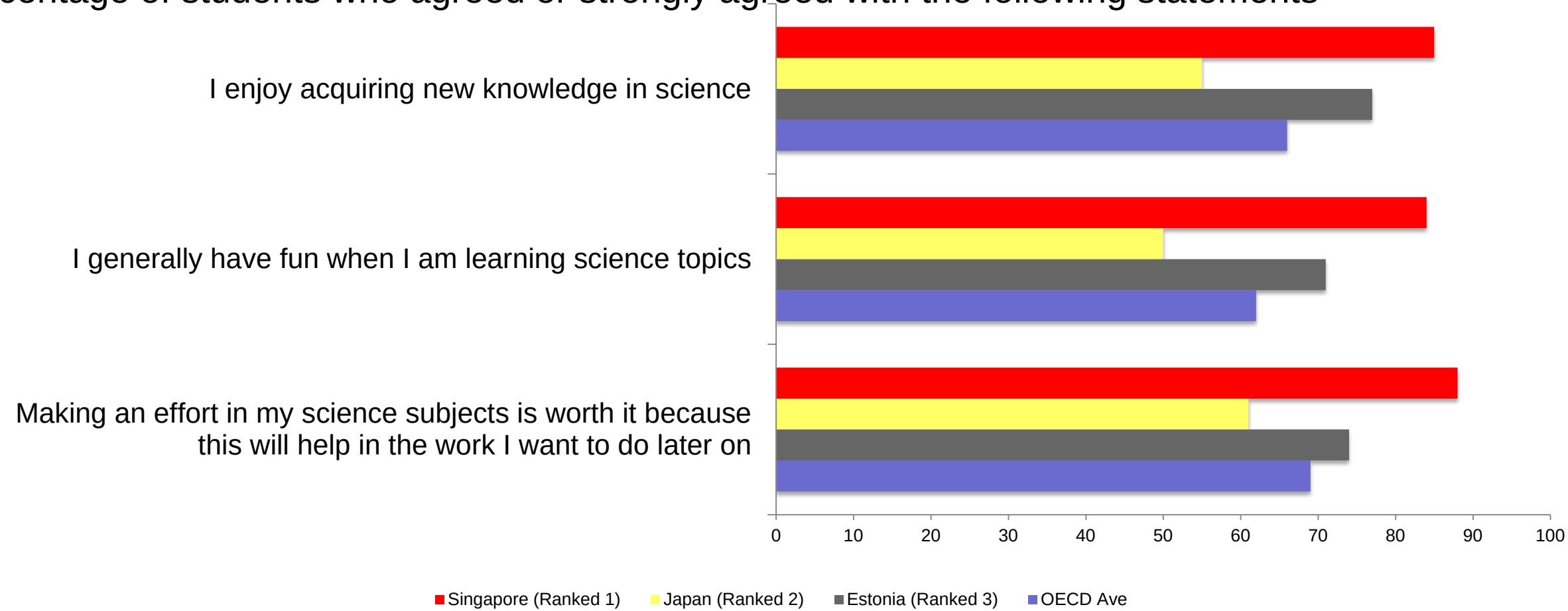
E Many things I learn in my <school science> subject(s) will help me to get a job



[Source: PISA Results 2015 (Vol I), Figure I.3.13, p. 127]

Singapore students enjoy learning science significantly greater than most students from top-performing countries.

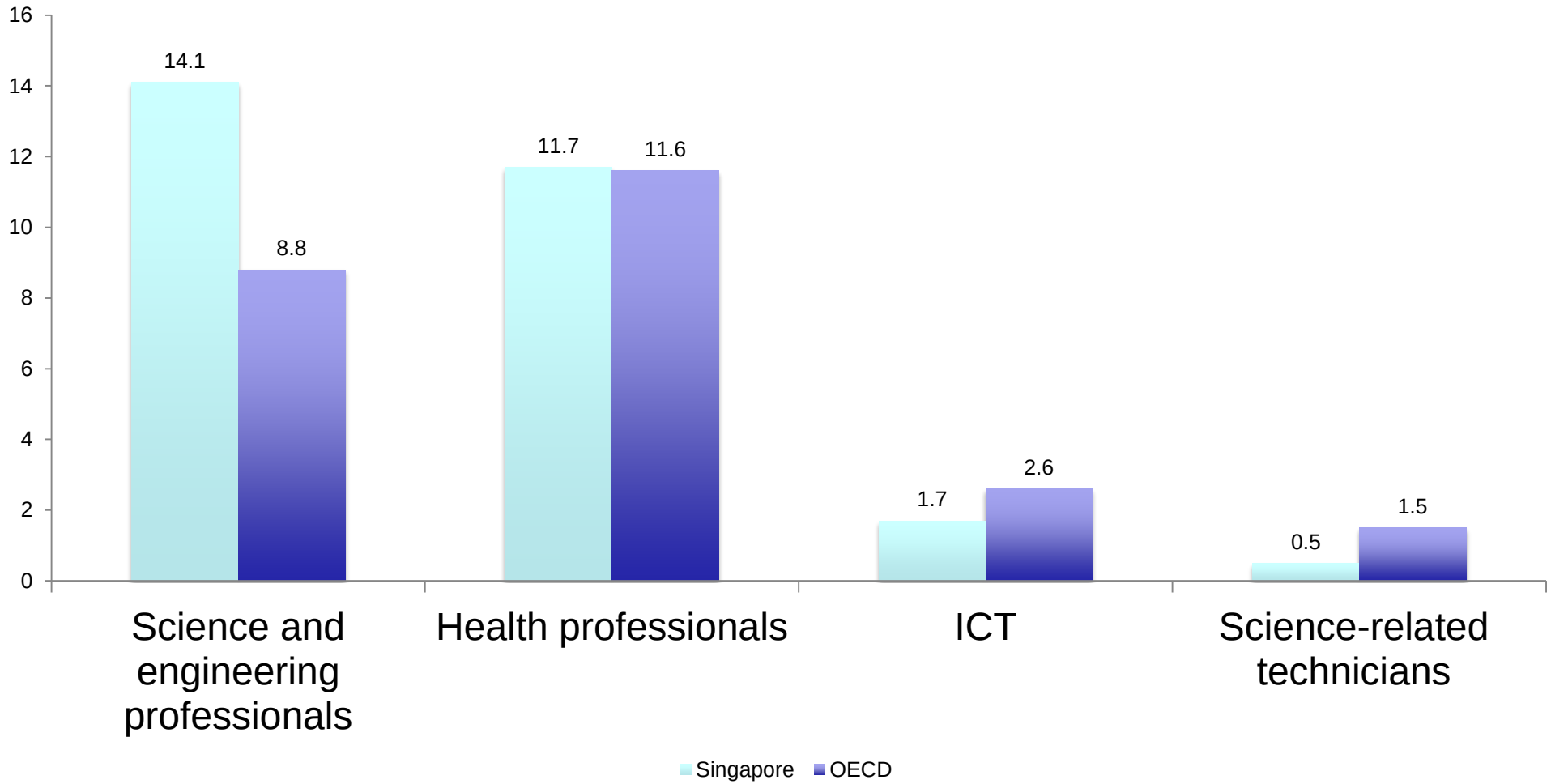
Percentage of students who agreed or strongly agreed with the following statements



Singapore students' enjoyment of learning science influences the type of careers they aspire to and choose to pursue.

OECD, 2016

A good portion of Singapore students aspire for a science-related career.



Singapore students have significantly greater inclination toward science and engineering profession than their international counterparts.

MOE, 2017

Singapore Students' Science Learning Self-efficacy (SLSE)

- Singaporean eighth graders show high SLSE in all dimensions, including 'conceptual understanding and higher-order cognitive skills', 'practical work (PW)', 'everyday application', and 'science communication'.

(Lin , Tan & Tsai, 2013)

Attributes that predispose students towards high learning outcomes

- High self-efficacy
- Motivation to learn science
- Interest in science related careers

Science Practical Assessment (SPA)

- Besides theory, students' practical skills also assessed through SPA as part of their GCE 'O' Level Examinations at Grade 10
- Skills tested include:

Skill Set 1 ***Performing and Observing***

- Demonstrate their ability to perform an experiment using familiar apparatus, materials and techniques safely and methodically; and
- Make relevant and accurate observations or measurements and record results in an appropriate manner

Skill Set 2 ***Analysing***

- process results, identify and comment on a key source of error
- draw conclusions which are consistent with obtained results

Skill Set 3 ***Planning***

- analyse a practical problem and produce an appropriate procedure for the investigation

The preparation and assessment of students on these skills could be a reason for students' high index of epistemic beliefs.

School Leadership and Science Performance in PISA 2015

- For Singapore, its investment in school leadership (Harris et al., 2014) and building of professional learning communities (PLCs), are reported to have small but significant summary effect on student achievement (Lomos, Hofman, & Bosker, 2011).

Singapore's School Leaders as Builders of Professional Learning Communities

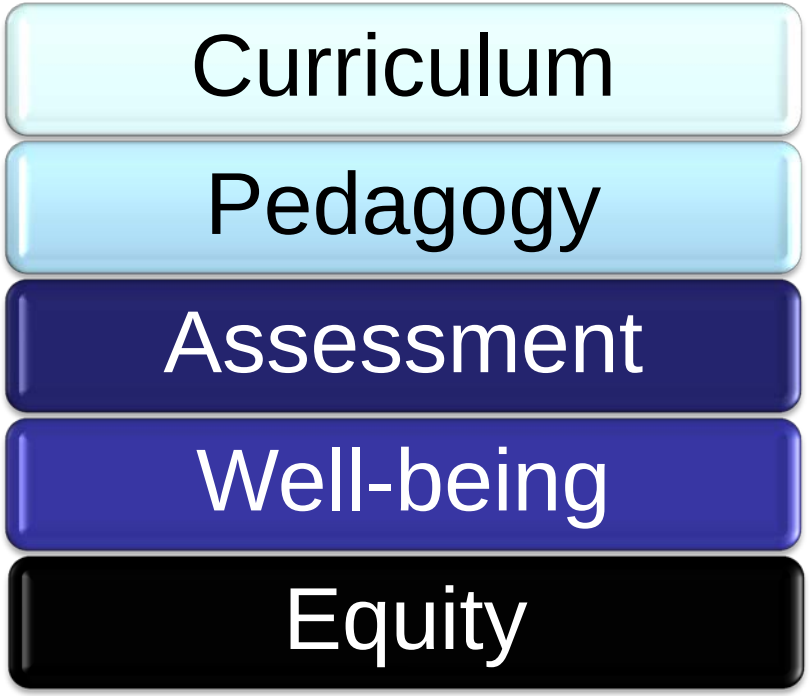
- In 2010, the MOE launched the Professional Learning Community (PLC) Model
- Encouraged schools to adopt a continuous process of improving instructional practice
- A survey of 96 schools reported the presence of conducive conditions for PLCs and a focus on student learning and outcomes, and collaborative learning (Lee & Lee, 2103).

Lessons from Singapore's Education Success

- Unity in purpose across society, educational system and individuals
- Strong alignment between policy intent from the top and enactments downstream
- Systematic and coherent efforts across multiple stakeholders ensure that policies filter down to the classroom level
- Strong adaptability of teachers allows the system to adapt to the evolving needs of the rapidly changing economic and social needs

Suggestions for moving forward: Where to next?

Areas of improvement



Curriculum

- Lack of learning objectives in the dimension of Metacognitive Knowledge, Analyze, and Evaluate in the primary science curriculum
- Limited focus on epistemic knowledge and metacognitive knowledge in general

[Lee, Kim & Yoon, 2015, Kwek, Lee & Wong, 2017]

Pedagogy

- Modest evidence of
  - Primary 5 students employing inference skills and communicating scientifically;
  - Secondary 3 students employing observation skills and analyzing patterns and relationships
- Comparatively fewer opportunities engaging in decision-making and creative problem-solving during scientific investigations
- Limited emphasis on scientific virtues
- Predominantly teacher-directed inquiry

[Kwek, Lee & Wong, 2017]

Assessment

- Assessment used mainly for summative rather than formative purposes
- Low proportion of major assignments or projects which demands higher order and intellectually demanding work

[Koh & Luke, 2009]

Shift in Knowledge and Skills

- Greater focus on epistemic knowledge of science (NOS) and metacognitive knowledge
- Emphasizing the importance of scientific virtues
- *Enhance scientific literacy with knowledge of scientific representational resources and their meaning potential*
- *A focus on abductive reasoning*

(Science Research Sharing Seminar, Science Education in Singapore: Where to next, 2017)

Emphasizing Scientific Practices

- More emphasis on scientific practices (and not just scientific knowledge) such as argumentation, knowledge generation and evaluation
- Greater student agency in conducting investigations
- Metacognitive self-review of learning by science students
- Embracing the literal and metaphorical *messiness* of science

(Science Research Sharing Seminar, Science Education in Singapore: Where to next, 2017)

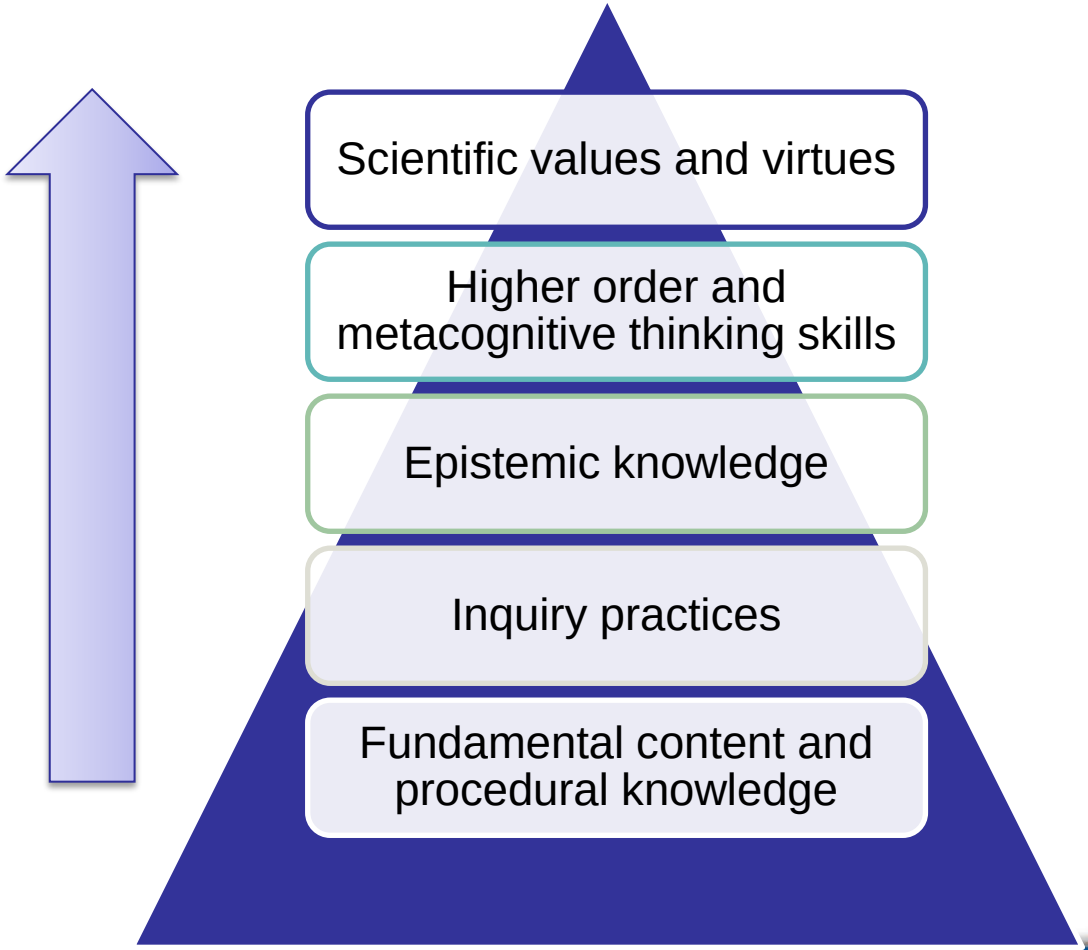
Shift in Pedagogy

- Exposing students to more ‘what if’ questions and non-routine problems
- Balancing of all aspects of scientific inquiry (providing more opportunities for students to engage in decision-making and creative problem solving)
- Teaching of metacognitive strategies and engaging in metacognitive talk
- Engaging students in multiple-text reading in the context of inquiry and problem solving
- Making greater connections to real life problems

(Science Research Sharing Seminar, Science Education in Singapore: Where to next, 2017)

Building on our strengths in science education

Further advancement of higher levels of scientific knowledge and skills are sought



Focusing on Student Well-being

- Test anxiety-pertains to the pressure to get higher marks and the concern about receiving poor grades
  - *I often worry that it will be difficult for me to take a test.*
  - *I worry I will get poor grades at school*
  - *I feel very anxious even if I am well prepared for a test*
  - *I get very tense when I study for a test"*
  - *I get nervous when I do not know how to solve a task at school.*
- Singapore has higher than OECD average test anxiety, which goes with higher achievement motivation.

Focusing on Student Well-being

Country	Mean Score	Index of Schoolwork-related Anxiety	Index of Exposure to Bullying
OECD Average	493	0.01	0
Singapore	**556**	**0.57**	**0.51**
Japan	538	0.26	-0.21
Estonia	534	-0.22	0.24
Chinese Taipei	532	0.39	-0.57
Finland	531	-0.41	0.23
Macao (China)	529	0.37	0.49
Canada	528	0.17	0.39
Hong Kong (China)	523	0.33	0.21
B-S-J-G China	518	0.23	0.1
Korea	516	0.1	-1.44
Australia	510	0.19	0.45
United Kingdom	509	0.25	0.4
United States	496	0.19	0.16

Source: OECD, 2017, Tables III.1.2, III.1.3.

Focusing on Student Well-being

- After accounting for students' performance and socio-economic status, students who reported that their science teachers adapt the lesson to the class's needs and knowledge were less likely to report feeling anxious
- Students were also less likely to report anxiety if the science teacher provides individual help when they are struggling.
- By contrast, negative teacher-student relations can undermine students' confidence and lead to greater anxiety.

(OECD, 2016)

Levers of Singapore's Educational Success are Key in Attaining Improvement in Key Science Outcomes

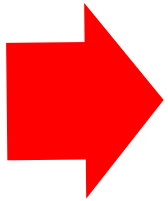
Four Levers of Singapore's Educational Success

1.Unity in purpose across society, educational system and individuals

2. Strong alignment between policy intent from the top and enactments downstream

3.Systematic and coherent efforts across multiple stakeholders

4. Adaptability of teaching force to dynamic policy and curriculum



Four Key Areas of Improvement

1.**Shifting pedagogies** (adaptive instruction that is more nuanced/tailored to different types of learners)

2. **Shifting skills and knowledge** (greater focus on epistemic knowledge, metacognitive knowledge, and abductive reasoning)

3**. Emphasizing scientific practices and virtues**

4. **Improving students' well-being**

5. Increasing equity in educational outcomes

THANK YOU!