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Summary of policy recommendations

- **Create instructional programs for poor achievers.** Poor-performing students are likely not learning from the standard science instruction designed for better performers. Instead, these students need to be identified and provided with attention and differentiated instructional strategies more suited to their needs.
- **Strengthen literacy training across the curriculum.** More effort should be exerted in improving the reading abilities and metacognitive reading strategies of Filipino students, particularly when a large proportion of learning activities in science involve reading textbooks and other written material.
- **Change perceptions regarding science.** It may be useful to create extra-curricular programs that will make students perceive the relevance of science in their lives, including their roles as involved citizens and their future occupations.
- **Improve school climate.** Programs and interventions that strengthen students' sense of belongingness and cooperation in school should be developed, with special program components for low-achieving students. A first step can be identifying the nature and causes of these experiences (because they may vary in different school contexts), and the programs can be designed based on the identified causes of the problematic school climate.
- **Increase students' access to ICT devices and connectivity.** Students' access to ICT devices and the internet at home should be improved. Teachers and students also need to be trained on how they can effectively use the internet to assist students' science learning.

Abstract

The Philippines performed abysmally in PISA 2018 science literacy assessment: only 22% of the 7,233 15-year-old Filipino students who participated in PISA achieved the minimum level of competency (Level 2) in science literacy (Organisation for Economic Cooperation and Development [OECD], 2019). This performance in the science assessment places the Philippines near the bottom of the 79 countries and economies that participated in PISA 2018. In a study that used a machine learning approach, we identified 15 variables that identified the poor-performing students in science literacy. These variables can be grouped into four clusters, namely, metacognitive reading strategies, classroom and school experiences, students' affect and motivation, and their family experiences and learning resources at home. Based on these results, we suggest a number of interventions that can address these non-cognitive variables that predict poor performance in science literacy.

Identifying Poor Performers in Science Literacy Using a Machine Learning Approach

Science literacy is becoming increasingly important, given the complexity of the current problems we face as a society. Looming crises in climate change, food inadequacy, public health, and the prevalence of online misinformation all stress the need for a science-literate society that can make informed decisions and strategies to address these concerns. Results of international assessments, however, show Filipino students' poor performance in science (Mullis et al., 2020; OECD, 2019). In the PISA 2018 cycle, only 22% of participating Filipino students demonstrated proficiency at Level 2

(minimum level) or higher in science literacy. It is, therefore, necessary to understand the factors that contribute to poor science performance.

The large number of available student-related variables measured in PISA 2018 allowed us to use a machine learning approach in determining a model that best predicts poor performance in the PISA 2018 science literacy assessment. This study used publicly available data from OECD (<https://www.oecd.org/pisa/data/2018database/>). PISA used a two-stage stratified sampling method to determine the Philippine sample: (a) randomly selecting 187 schools from 17 regions in the country and (b) randomly selecting students from these schools. This resulted in a final sample of 7,233 students from the Philippines. These were 15-year-old students who were enrolled in school during the time of testing.

A binary classification model that grouped the sample data into two classes, low performance (scoring at PISA levels 1b and below) and high performance (scoring at levels 1a, 2, and higher), was used. Although we had initially planned to study 85 variables, the removal of missing data and minimization of negative depressors resulted in 73 variables (including the science literacy score) that were used in training the model. A random forest classifier proved to be the best model in terms of accuracy. The model performed well on three metrics (classification accuracy, precision, and recall). Shapley additive explanations (SHAP) were used to identify the variables that predicted poor performance. These 15 variables (see Table 1) can be classified into four clusters: metacognitive reading strategies, classroom and school experiences, affective or motivational experiences, and family experiences and home learning resources. These clusters are discussed below.

Student-related variables	PISA Items
Metacognitive awareness of reading strategies	High perceived effectiveness of low-level reading strategies: I summarise the text in my own words I underline important parts of the text I quickly read through the text twice Low perceived effectiveness of high-level reading strategies: I concentrate on the parts of the text that are easy to understand After reading the text, I discuss its content with other people
Classroom and school experiences	Low sense of belonging Low perceived cooperation among students Low experience with bullying Low experience of students not listening to what the teacher says
Affective and motivational experiences	Low motivation to master assigned learning tasks High expected occupational status High feelings of pride about the things they accomplished
Family experiences and learning resources at home	Low mother's educational attainment High parents' occupational status Low number of smartphones with internet access

Metacognitive awareness of reading strategies, or the awareness and control of one's own reading ability, identified Filipino students with poor science literacy performance. Poor-performing students more often perceived low-level reading strategies as more effective than high-level strategies for understanding the text they read. If a large part of students' learning in science is based on reading and understanding written material (textbooks or modules), then it makes sense that knowledge of effective reading strategies will influence their science literacy.

A low sense of belonging and perception of a lack of cooperation among students also identified poor-performing science students. This finding un-

derscores the importance of social factors in the classroom and school levels in students' academic performance. Given that learning activities in science subjects often entail working with other students, a sense of belonging and cooperation are likely important for good academic performance.

Poor-performing students were also identified by their low motivation to master tasks. However, these students also reported high expected occupational status and a feeling of pride in their accomplishments. One possible explanation for this result is that students do not consider perseverance in mastering one's tasks or science literacy important factors in their future occupations or in their sense of pride or self-worth.

Three variables that predict poor performance are related to students' family and their resources at home. First, we found that their mothers' low level of educational attainment predicted students' poor science performance. Second, parents' higher occupational status also predicted poor performance. It is likely that these students are exposed to elders with occupations that are unrelated to science, possibly leading them to view science mastery as irrelevant to their future job prospects. Lastly, poor performers can be identified by their lack of smartphones with internet access at home. It is likely that access to the internet provides students with the means to communicate and collaborate with their classmates and to look for information online to support their learning.

Conclusions and recommendations

Using a machine learning approach, we determined 15 factors or variables that identified poor-performing Filipino students in the PISA 2018 science literacy assessment. These factors include students' metacognitive reading strategies, their classroom and school experiences, their motivation, and their family experiences and home learning resources. These factors are not typically addressed by educational interventions that tend to focus on instruction, curriculum, and learning resources. But the factors identified in the study clearly predict poor performance in science literacy, and at the very least, they should help educators identify the students that are vulnerable to low achievement and that need learning interventions. But the findings also point to new areas for intervention that relate to students' reading strategies for effective processing of science texts and students' social and motivational experiences in school that may also be influenced by their family's occupational and educational profiles. We suggest a number of policy recommendations to address them.

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