



SCIENTIFIC CHARACTER AND SCIENTIFIC LITERACY ACROSS FOUR SOUTHEAST ASIAN COUNTRIES: A PISA 2022 ANALYSIS OF CURIOSITY AND INTEREST IN SCIENCE WITH IMPLICATIONS FOR PHYSICS EDUCATION

Mohammad Naim Bahar¹, Sentot Kusairi^{1*}, Sunaryono¹, Parno Parno¹, Khusaini¹, Samsul
Irpan², Noor Mohammad Azizi³, Fazalullah Marufi⁴, Riswanda Himawan⁵, Zohaib Hassan
Sain⁶

¹Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang,
Indonesia

²Universitas Islam Negeri Mataram, Mataram 83116, Indonesia

³Department of Nuclear and Atomic Physics, Faculty of Physics, Kabul University, Kabul, Afghanistan

⁴Department of Physics, Faculty of Education, Urozgan University, Afghanistan

⁵Doctoral Program of Indonesian Language Education, Faculty of Letters, Universitas Negeri Malang, Malang,
Indonesia

⁶Superior University, 17 km Main Raiwind Road, Lahore, Pakistan

*sentot.kusairi.fmipa@um.ac.id

Abstract

Scientific literacy is essential for enabling young people to interpret evidence, explain natural phenomena, and participate responsibly in societies increasingly shaped by science and technology. This study investigated how two dimensions of scientific character - curiosity and interest in science - are associated with scientific literacy across Indonesia, Malaysia, Singapore, and Thailand, and considered their implications for character-oriented physics education. A comparative quantitative design was employed using PISA 2022 data from 35,609 students. Scientific literacy was represented by ten science plausible values, curiosity by CURIOAGR, and interest in science by the item identifying science as a favorite subject; socio-economic status (ESCS) and gender were included as covariates. Country-specific multiple regression analyses revealed that curiosity was positively associated with scientific literacy in all four countries. Interest in science showed positive adjusted associations in Malaysia, Singapore, and Thailand, but a small negative association in Indonesia. ESCS emerged as the strongest predictor in every country. The models explained 10.6% of variance in Indonesia, 19.7% in Malaysia, 21.4% in Singapore, and 26.7% in Thailand. These findings indicate that scientific character is meaningfully associated with scientific literacy, although its contribution varies across national contexts and remains strongly conditioned by socio-economic inequality. The study underscores the importance of physics instruction that deliberately cultivates curiosity, sustained scientific engagement, evidence-based reasoning, and equitable access to meaningful inquiry, thereby supporting scientifically literate and responsible global citizens.

Keywords *Scientific Literacy, Scientific Character, Curiosity, Interest in Science, Physics Education*

INTRODUCTION

Scientific literacy has become a central educational outcome in societies where everyday decisions, public policy, and economic development are increasingly shaped by scientific and technological knowledge. In the PISA framework, scientific literacy refers to students' capacity to engage with science-related issues and ideas by explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence (OECD, 2023a). This definition positions scientific literacy not simply as the recall of concepts, but as the ability to mobilize knowledge and reasoning in authentic contexts.

The PISA 2022 results also reveal substantial differences in science performance and educational equity across participating systems (OECD, 2023b). Southeast Asia provides a particularly informative comparative setting because Indonesia, Malaysia, Singapore, and Thailand share regional connections while differing markedly in educational resources, socio-economic conditions, instructional traditions, and observed science outcomes. Such diversity makes it possible to investigate whether student dispositions show consistent relationships with scientific literacy across contexts or whether their contribution depends on national conditions.

This study approaches those dispositions through the conceptual lens of scientific character. Here, scientific character refers to durable orientations that support engagement with scientific inquiry, especially a willingness to question, explore, sustain attention to scientific problems, and reason from evidence. It is not treated as a separate validated PISA scale or as a new psychometric composite. Rather, the term is used to interpret two measured dispositions available in the analytical data: curiosity and interest in science. This distinction is important because it keeps the conceptual contribution of the study aligned with the actual PISA variables.

Curiosity is especially relevant to science learning because it directs attention toward uncertainty and motivates information seeking. In secondary science, inquiry-related curiosity has been associated with laboratory engagement and inquiry abilities, suggesting that curiosity can connect students' desire to know with productive scientific activity (Wu et al., 2018). Interest represents a related but distinct motivational orientation. Across academic domains, students tend to achieve more strongly in areas in which they report greater interest even after background factors are considered (Jansen et al., 2016). A large three-level meta-analysis likewise found a positive overall relationship between attitudes toward science and science achievement, although the strength of this relationship varied by the type of attitude measured (Mao et al., 2021).

International assessment research further suggests that achievement cannot be explained by cognitive indicators alone. Analyses of TIMSS and PISA have shown that non-cognitive characteristics, especially self-beliefs and motivational variables, contribute to academic performance, while socio-economic status remains a powerful structural correlate (Lee & Stankov, 2018). Within PISA science, profiles of motivation and beliefs are also related to the effort students invest and to their performance (Hofverberg et al., 2022). These findings support a model in which scientific dispositions matter, but operate within wider opportunity structures.

For physics education, the connection between disposition and opportunity is particularly consequential. Inquiry-oriented science instruction can support meaningful engagement when students are guided in asking questions, collecting evidence, interpreting data, and constructing explanations. Cross-national analyses show that the form and level of teacher guidance matter: guided inquiry can be associated with stronger outcomes than unguided inquiry (Aditomo & Klieme, 2020), and high- and low-achieving students report different patterns of inquiry-based instruction (Forbes et al., 2020). Meta-analytic evidence also indicates that innovative, inquiry-oriented and context-oriented approaches can

improve both achievement and student attitudes when designed well (Savelsbergh et al., 2016).

Interest in science is developmental rather than fixed. Longitudinal research shows reciprocal relationships among interest, self-concept, achievement, and intentions to pursue science and technology (Potvin et al., 2020). Interest and self-concept are also important for science aspirations, including gendered differences in students' future orientation toward science (Kang et al., 2021). At the same time, classroom discourse may fail to constitute a meaningful object of interest for some students, which complicates the common assumption that students simply 'lose' an interest they previously possessed (Anderhag et al., 2016). Experimental and longitudinal evidence further suggests that interest and knowledge can reinforce one another over time (Rotgans & Schmidt, 2017).

Physics learning additionally requires epistemic practices: students must decide what counts as evidence, connect representations, evaluate explanations, and justify conclusions. Research in physics problem-solving environments shows that epistemic cognition is intertwined with students' scientific practices rather than being reducible to factual knowledge (Lindfors et al., 2020). Inquiry-oriented interventions can strengthen scientific process skills and attitudes (Irwanto, 2022), and classroom inquiry can increase secondary students' interest in science and technology (Potvin et al., 2017). Nevertheless, international evidence cautions against assuming that more frequent inquiry automatically produces higher achievement. The association can differ by country, by the degree of guidance, and by how inquiry is enacted (Cairns & Areepattamannil, 2019; Jerrim et al., 2019). In other words, pedagogy must cultivate curiosity and interest while preserving conceptual structure and evidence-based reasoning, consistent with contemporary interest-development perspectives (Renninger & Hidi, 2016).

Despite this literature, relatively little comparative work has examined curiosity and science interest together as dimensions of scientific character across several Southeast Asian education systems while simultaneously controlling for socio-economic status and gender. The present study addresses this gap using PISA 2022 data from Indonesia, Malaysia, Singapore, and Thailand. It asks: (1) What descriptive patterns of scientific literacy, curiosity, science interest, socio-economic status, and gender are observed across the four analytical samples? (2) How are curiosity and interest in science associated with scientific literacy within each country? (3) Do these relationships remain after ESCS and gender are controlled? and (4) What do the shared and context-dependent patterns imply for character-oriented physics education?

METHODS

Research Design and Participants

A comparative quantitative design was used to examine within-country relationships among scientific dispositions, socio-economic background, gender, and scientific literacy. The analytical data comprised 35,609 PISA 2022 student records from four Southeast Asian countries: Indonesia ($n = 13,439$), Malaysia ($n = 7,069$), Singapore ($n = 6,606$), and Thailand ($n = 8,495$). Country-specific models were estimated rather than imposing a

single pooled coefficient across education systems, allowing the analysis to identify both recurring and context-dependent patterns.

Measures

Scientific literacy was represented by the ten PISA science plausible values (PV1SCIE-PV10SCIE). Descriptive science scores were summarized across the ten plausible values, and regression results were combined across the same set of plausible values. Curiosity was operationalized with CURIOAGR. Interest in science was represented by the item indicating whether science was a favourite subject. Socio-economic status was measured using the PISA index of economic, social and cultural status (ESCS). Gender was included as a binary covariate coded so that the reported coefficient represents male students. In this article, curiosity and interest in science are interpreted as dimensions of scientific character; they are not combined into a single score.

Data Screening and Statistical Analysis

Missingness was modest for the variables used in the four-country models. Curiosity missingness ranged from 1.56% in Singapore to 5.14% in Malaysia; science-interest missingness ranged from 1.20% in Singapore to 8.57% in Malaysia; and ESCS missingness remained below 1.1% in all four countries. Listwise deletion was used for missing predictor values in the regression models, producing valid model samples of 12,386 students in Indonesia, 6,278 in Malaysia, 6,462 in Singapore, and 7,928 in Thailand.

The analysis proceeded in four stages. First, descriptive statistics were computed for scientific literacy, curiosity, interest in science, ESCS, and gender. Second, Pearson correlations were examined between each predictor and scientific literacy. Third, variance inflation factors (VIFs) were inspected to evaluate multicollinearity. Fourth, separate multiple regression models were fitted for each country, with scientific literacy as the outcome and curiosity, interest in science, ESCS, and gender entered simultaneously. Standardized coefficients, standard errors, 95% confidence intervals, p values, and adjusted R² were used to compare associations and model explanatory power. Across all models, VIF values ranged from 1.004 to 1.117, indicating no problematic multicollinearity.

RESULTS

Descriptive Profile of the Four Countries

Table 1 summarizes the analytical samples. Singapore had the highest descriptive scientific-literacy mean, followed by Thailand, Malaysia, and Indonesia. Singapore also had the highest mean curiosity, science interest, and ESCS in the available data. The science-interest response distribution was broadly positive in each country: the combined proportion selecting 'agree' or 'strongly agree' was 63.9% in Indonesia, 68.2% in Malaysia, 69.3% in Singapore, and 63.3% in Thailand.

Table 1. Descriptive characteristics of the analytical samples

Country	N	Scientific literacy (SD)	M Curiosity M (SD)	Science interest (SD)	M ESCS (SD)	M Male (%)
Indonesia	13,439	395.31 (70.19)	0.075 (0.866)	2.675 (0.716)	-1.448 (1.047)	48.9
Malaysia	7,069	417.16 (77.56)	0.106 (0.997)	2.782 (0.775)	-0.662 (1.036)	48.9
Singapore	6,606	560.98 (99.31)	0.133 (1.040)	2.858 (0.874)	0.290 (0.833)	50.8
Thailand	8,495	429.02 (93.84)	0.018 (0.908)	2.669 (0.785)	-0.963 (1.201)	47.6

Note. Scientific-literacy means and standard deviations are descriptive averages across the ten science plausible values within the analytical file.

Bivariate Associations

Curiosity was positively correlated with scientific literacy in every country, with coefficients ranging from $r = .185$ in Singapore to $r = .275$ in Malaysia. ESCS showed larger positive correlations in all four systems, from $r = .302$ in Indonesia to $r = .493$ in Thailand. Interest in science displayed a more context-dependent pattern: the correlation was positive in Malaysia, Singapore, and Thailand, but nearly zero and slightly negative in Indonesia. Gender correlations were small in all four countries (Table 2).

Table 2. Pearson correlations with scientific literacy

Country	Curiosity	Interest in science	ESCS	Gender (male)
Indonesia	.192	-.025	.302	-.039
Malaysia	.275	.171	.403	-.078
Singapore	.185	.226	.447	.036
Thailand	.253	.171	.493	-.041

Country-Specific Multiple Regression

The four regression models differed substantially in explanatory power. Adjusted R² was .106 for Indonesia, .197 for Malaysia, .214 for Singapore, and .267 for Thailand (Table 3). Curiosity remained positive and statistically significant after science interest, ESCS, and gender were controlled in every country. ESCS was the largest standardized predictor in all four models. Interest in science remained positive in Malaysia, Singapore, and Thailand, whereas Indonesia showed a small negative adjusted coefficient. Male gender was

negatively associated with scientific literacy in Malaysia and Thailand, but was not statistically significant in Indonesia or Singapore.

Table 3. Model summaries by country

Country	Valid N	Adjusted R2
Indonesia	12,386	.106
Malaysia	6,278	.197
Singapore	6,462	.214
Thailand	7,928	.267

Table 4. Standardized coefficients from country-specific regression models

Country	Predictor	beta	SE	95% CI	p
Indonesia	Curiosity	.158	.011	[.136, .180]	< .001
	Interest in science	-.053	.011	[-.075, -.030]	< .001
	ESCS	.267	.013	[.240, .293]	< .001
	Gender (male)	-.036	.018	[-.074, .002]	.060
Malaysia	Curiosity	.174	.015	[.145, .203]	< .001
	Interest in science	.093	.016	[.061, .126]	< .001
	ESCS	.347	.015	[.318, .376]	< .001
	Gender (male)	-.061	.014	[-.089, -.034]	< .001
Singapore	Curiosity	.081	.015	[.050, .111]	< .001
	Interest in science	.146	.014	[.118, .173]	< .001
	ESCS	.398	.012	[.374, .421]	< .001
	Gender (male)	.018	.014	[-.011, .046]	.225
Thailand	Curiosity	.164	.011	[.142, .186]	< .001
	Interest in science	.097	.011	[.075, .120]	< .001
	ESCS	.446	.012	[.423, .469]	< .001
	Gender (male)	-.054	.014	[-.082, -.027]	< .001

For curiosity, the standardized coefficients were $\beta = .158$ in Indonesia, $.174$ in Malaysia, $.081$ in Singapore, and $.164$ in Thailand. For ESCS, the corresponding coefficients were $\beta = .267$, $.347$, $.398$, and $.446$. The magnitude of the ESCS coefficients, together with the bivariate correlations, shows that socio-economic conditions consistently account for a larger share of between-student differences in scientific literacy than the two disposition variables included here.

DISCUSSION

The central finding is that curiosity shows a consistent positive relationship with scientific literacy across all four Southeast Asian education systems. This pattern is important because it persists after interest in science, socio-economic status, and gender are considered simultaneously. The result supports the interpretation of curiosity as a meaningful dimension of scientific character: students who are more disposed to seek information and engage with uncertainty also tend to demonstrate stronger capacity to reason with scientific knowledge and evidence. This interpretation is consistent with inquiry-related curiosity research showing links among curiosity, engagement, and inquiry abilities (Wu et al., 2018).

Curiosity as a Cross-National Dimension of Scientific Character

The cross-country consistency of curiosity is more informative than the absolute size of any one coefficient. Malaysia, Thailand, and Indonesia showed similarly moderate positive standardized coefficients, whereas Singapore's coefficient was smaller but remained statistically significant. A smaller coefficient in a high-performing system should not be interpreted as indicating that curiosity is educationally unimportant. Regression coefficients represent incremental associations given the other variables in the model and the distribution of scores within each country. In systems where instructional structures, prior achievement, and resources are strong, the additional between-student variation associated with curiosity may simply be narrower.

For physics education, this result strengthens the case for learning designs that make curiosity productive. Curiosity is most educationally valuable when questions lead to disciplined investigation rather than unstructured activity. Guided inquiry, phenomenon-based prompts, student-generated questions, prediction-explanation cycles, and evidence-based argumentation can create a pathway from wanting to know to knowing how to investigate. This is consistent with evidence that guided forms of inquiry can be more productive than unguided forms (Aditomo & Klieme, 2020) and that patterns of inquiry differ among students with different achievement profiles (Forbes et al., 2020).

Interest in Science Is More Context Dependent

Interest in science displayed a different cross-national pattern. Positive adjusted associations were observed in Malaysia, Singapore, and Thailand, consistent with literature linking subject interest and achievement (Jansen et al., 2016; Mao et al., 2021). Indonesia, however, showed a small negative adjusted coefficient ($\beta = -.053$) after curiosity, ESCS, and gender were controlled. Because the bivariate correlation in Indonesia was already close to zero ($r = -.025$), this result should not be read as evidence that interest harms achievement. Instead, it indicates that the residual component of the single interest item behaves differently in the Indonesian sample once other variables are considered.

Several interpretations warrant future testing. The favourite-subject item may capture affective preference without measuring sustained cognitive engagement, so high interest need not translate directly into the specific reasoning competencies assessed by PISA. The relationship may also be conditioned by access to high-quality instructional opportunities:

students can like science while having limited opportunities to engage in laboratory work, evidence evaluation, or extended problem solving. More generally, research on science interest suggests that classroom discourse and learning conditions help constitute the object of interest itself (Anderhag et al., 2016), and longitudinal work indicates reciprocal relations among interest, self-concept, achievement, and science aspirations (Potvin et al., 2020; Kang et al., 2021).

Socio-Economic Status as the Dominant Structural Predictor

ESCS was the strongest predictor of scientific literacy in every model. Its standardized coefficient ranged from .267 in Indonesia to .446 in Thailand, and its bivariate correlation ranged from .302 to .493. The consistency of this pattern places an important boundary around character-oriented interpretations: scientific character develops and operates within unequal opportunity structures. Curiosity and interest can support learning, but they cannot substitute for access to qualified teachers, adequate learning materials, digital resources, laboratory opportunities, supportive school climates, and time for sustained intellectual work.

Accordingly, a productive educational response is not to choose between character development and equity. Physics education should cultivate curiosity and interest while simultaneously expanding access to meaningful scientific experiences. Meta-analytic and intervention research shows that innovative and inquiry-oriented instruction can strengthen attitudes as well as learning when it is carefully designed (Savelsbergh et al., 2016; Irwanto, 2022; Potvin et al., 2017). Yet cross-national PISA research also warns that inquiry frequency by itself is not a guarantee of higher achievement (Cairns & Aarepattamannil, 2019; Jerrim et al., 2019). The instructional issue is therefore the quality, guidance, and epistemic purpose of inquiry rather than the quantity of hands-on activity alone.

Implications for Character-Oriented Physics Education

The results suggest four practical principles for physics instruction. First, lessons should begin from intellectually generative phenomena that invite students to notice discrepancies and formulate investigable questions. Second, teachers should scaffold inquiry so that curiosity is connected to conceptual models, measurement, data interpretation, and argument from evidence. Third, sustained interest should be supported through relevant contexts and opportunities for students to see how physics explains consequential phenomena in everyday life, technology, energy, environment, and society. Fourth, equity should be treated as a pedagogical condition: students need access to the tools, time, guidance, and participation structures required to convert curiosity into competence.

These principles also sharpen the meaning of scientific character. In this study, scientific character is not a moral label attached to high test performance. It describes dispositions that can support responsible scientific participation: asking worthwhile questions, persisting with uncertainty, evaluating evidence, revising explanations, and remaining engaged with scientific ideas. Such dispositions align with the epistemic

demands of physics problem solving (Lindfors et al., 2020) and with theories that view interest as developing through repeated, supported engagement rather than as a fixed personal trait (Renninger & Hidi, 2016).

CONCLUSION

Across Indonesia, Malaysia, Singapore, and Thailand, curiosity was positively associated with scientific literacy after interest in science, socio-economic status, and gender were controlled. This common pattern supports the use of curiosity as a meaningful dimension of scientific character in comparative science-education research. Interest in science was more context dependent: it was positively associated with scientific literacy in Malaysia, Singapore, and Thailand, but showed a small negative adjusted association in Indonesia. ESCS was the strongest predictor in every country, demonstrating that scientific dispositions operate within persistent socio-economic inequalities.

The implication for physics education is therefore dual. Students need learning environments that cultivate questioning, sustained engagement, evidence-based reasoning, and epistemic responsibility, but they also need equitable opportunities to participate in such learning. Character-oriented physics education is strongest when curiosity is transformed into guided inquiry, interest is sustained through meaningful contexts, and access to high-quality scientific experiences is treated as a condition of educational justice. In that combination, scientific character can contribute to the broader goal of developing scientifically literate young people prepared for responsible participation in a science- and technology-intensive world.

ACKNOWLEDGMENT

The authors acknowledge the OECD Programme for International Student Assessment (PISA) for making international assessment data available for educational research. The authors also acknowledge the institutional and scholarly support that contributed to the development of this study. **ChatGPT (OpenAI) and Grammarly were used solely to assist with English-language editing, including grammar, clarity, and stylistic refinement. The authors reviewed and approved all revisions and remain fully responsible for the content, interpretations, and conclusions of the manuscript.**

Conflict of Interest The authors declare that they have no conflict of interest.

REFERENCES

- Aditomo, A., & Klieme, E. (2020). Forms of inquiry-based science instruction and their relations with learning outcomes: Evidence from high and low-performing education systems. *International Journal of Science Education*, 42(4), 504-525. <https://doi.org/10.1080/09500693.2020.1716093>
- Anderhag, P., Wickman, P.-O., Bergqvist, K., Jakobson, B., Hamza, K. M., & Säljö, R. (2016). Why do secondary school students lose their interest in science? Or does it never emerge? A possible and overlooked explanation. *Science Education*, 100(5), 791-813. <https://doi.org/10.1002/sce.21231>
- Cairns, D., & Aarepattamannil, S. (2019). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education*, 49(1), 1-23. <https://doi.org/10.1007/s11165-017-9639-x>
- Forbes, C. T., Neumann, K., & Schiepe-Tiska, A. (2020). Patterns of inquiry-based science instruction and student science achievement in PISA 2015. *International Journal of Science Education*, 42(5), 783-806. <https://doi.org/10.1080/09500693.2020.1730017>

- Hofverberg, A., Eklöf, H., & Lindfors, M. (2022). Who makes an effort? A person-centered examination of motivation and beliefs as predictors of students' effort and performance on the PISA 2015 science assessment. *Frontiers in Education*, 6, 791599. <https://doi.org/10.3389/feduc.2021.791599>
- Irwanto, I. (2022). The impact of research-oriented collaborative inquiry learning on pre-service teachers' scientific process skills and attitudes. *Journal of Technology and Science Education*, 12(2), 410-425. <https://doi.org/10.3926/jotse.1583>
- Jansen, M., Lüdtke, O., & Schroeders, U. (2016). Evidence for a positive relation between interest and achievement: Examining between-person and within-person variation in five domains. *Contemporary Educational Psychology*, 46, 116-127. <https://doi.org/10.1016/j.cedpsych.2016.05.004>
- Jerrim, J., Oliver, M., & Sims, S. (2019). The relationship between inquiry-based teaching and students' achievement: New evidence from a longitudinal PISA study in England. *Learning and Instruction*, 61, 35-44. <https://doi.org/10.1016/j.learninstruc.2018.12.004>
- Kang, J., Keinonen, T., & Salonen, A. (2021). Role of interest and self-concept in predicting science aspirations: Gender study. *Research in Science Education*, 51(Suppl 1), 513-535. <https://doi.org/10.1007/s11165-019-09905-w>
- Lee, J., & Stankov, L. (2018). Non-cognitive predictors of academic achievement: Evidence from TIMSS and PISA. *Learning and Individual Differences*, 65, 50-64. <https://doi.org/10.1016/j.lindif.2018.05.009>
- Lindfors, M., Bodin, M., & Simon, S. (2020). Unpacking students' epistemic cognition in a physics problem-solving environment. *Journal of Research in Science Teaching*, 57(5), 695-732. <https://doi.org/10.1002/tea.21606>
- Mao, P., Cai, Z., He, J., Chen, X., & Fan, X. (2021). The relationship between attitude toward science and academic achievement in science: A three-level meta-analysis. *Frontiers in Psychology*, 12, 784068. <https://doi.org/10.3389/fpsyg.2021.784068>
- OECD. (2023a). PISA 2022 assessment and analytical framework. OECD Publishing. <https://doi.org/10.1787/dfe0bf9c-en>
- OECD. (2023b). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. <https://doi.org/10.1787/53f23881-en>
- Potvin, P., Hasni, A., & Sy, O. (2017). Using inquiry-based interventions to improve secondary students' interest in science and technology. *European Journal of Science and Mathematics Education*, 5(3), 262-270. <https://doi.org/10.30935/scimath/9510>
- Potvin, P., Hasni, A., Sy, O., & Riopel, M. (2020). Two crucial years of science and technology schooling: A longitudinal study of the major influences on and interactions between self-concept, interest, and the intention to pursue S&T. *Research in Science Education*, 50, 1739-1761. <https://doi.org/10.1007/s11165-018-9751-6>
- Renninger, K. A., & Hidi, S. E. (2016). *The power of interest for motivation and engagement*. Routledge.
- Rotgans, J. I., & Schmidt, H. G. (2017). The relation between individual interest and knowledge acquisition. *British Educational Research Journal*, 43(2), 350-371. <https://doi.org/10.1002/berj.3268>
- Savelsbergh, E. R., Prins, G. T., Rietbergen, C., Fechner, S., Vaessen, B. E., Draijer, J. M., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review*, 19, 158-172. <https://doi.org/10.1016/j.edurev.2016.07.003>
- Wu, P.-H., Kuo, C.-Y., Wu, H.-K., Jen, T.-H., & Hsu, Y.-S. (2018). Learning benefits of secondary school students' inquiry-related curiosity: A cross-grade comparison of the relationships among learning experiences, curiosity, engagement, and inquiry abilities. *Science Education*, 102(5), 917-950. <https://doi.org/10.1002/sce.21456>