Factors Influencing Vietnamese Students' Science Literacy: A Structural Equation Model from PISA 2015 Data

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ABSTRACT: *Prior research has demonstrated that different non-cognitive factors influence students' science literacy. The present research investigates the relationships among students' perceptions of their science teachers, their non-cognitive outcomes (epistemological beliefs, science interests and usefulness of science) and the influence of these factors on students' science literacy. The data includes 5,826 15-year-old students (52.2% male and 47.8% female) who participated in the Programme for International Student Assessment (PISA) in 2015. The research revealed a meaningful pattern of complex relationships among non-cognitive factors and their influence on students' science literacy, enhancing and clarifying previous research findings with both theoretical and practical significance. The results of confirmatory factor analysis show that all items in each non-cognitive outcome had reasonable factor loading, and the model had good fit indices [RMSEA = 0.037; CFI = 0.931: TLI = 0.923; SRMR = 0.032]. The results of structural equation modeling (SEM) show good fits, suggesting that students' science interests directly influence their science literacy. Furthermore, students' perceptions of their science teachers, epistemological beliefs and usefulness of science indirectly influence science literacy through their science interests. Evidence from PISA Vietnam 2015 data also shows the insignificant path of the usefulness of science to science literacy.*

KEYWORDS: **SEM, science literacy, usefulness of science, epistemological beliefs, science interests, perceptions of science teachers.**

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1. Introduction

In many countries, various research problems have been raised on the basis of exploring PISA data. According to the OECD (2006), science and technology disciplines are less attractive, and the proportion of students in some OECD countries who are studying science and technology in universities has decreased markedly, especially between 1995 and 2005 (Potvin & Hasni, 2014). The reasons explaining this are varied, but students' attitudes towards science can play an important role (OECD, 2006). Thus, in 2006 and 2015, the International Student Assessment Program (PISA) focused on student competencies in science. For this, PISA combined several indicators by assessing the basic questionnaire items of its international testing initiative (Krapp & Prenzel, 2011), including students' attitudes toward science.

The most visible outcome of the PISA assessment is a ranking based on a national-level composite score of competencies. These results have broad social implications and are being used even to explain reforms in some countries' education laws. The PISA reports are seen by some authors as a stimulating opportunity to think critically about the goals of schools.

PISA data is suitable for investigating the relationship between science literacy and attitudes toward science. This relationship has previously been studied at the individual level, showing some positive correlations between, for example, the usefulness of science, and epistemological belief and science literacy (Dolin & Evans,

2011). Marsh et al. (2006), and Fonseca et al. (2011) found an unexpected negative correlation between achievements and attitudes between countries. Furthermore, Täht and Must (2013) found a lack of scalar invariance in educational achievement and learning attitudes, suggesting that the relationship between these variables may have different implications at the national level and at the student level within countries. In addition, the items in the students' questionnaire can yield valuable information about those relationships.

The question of whether these relationships are common in different countries, along with the use of PISA national GPA to study the relationship between academic attitudes and educational achievement, needs further investigation. To explore this relationship, many researchers used advanced data analysis methods. Such as using regression can yield a more complete description of functional changes rather than focusing attention exclusively on the mean (Koenker, 2005).

Vietnam has participated in the PISA since 2012, and until now, through the assessment cycles, Vietnamese students have consistently achieved high results in all three areas: Mathematics, Science and Reading. In addition to the general purposes of PISA like all other countries, the Ministry of Education and Training has joined PISA with a number of separate purposes, including (1) actively integrating into international education; (2) contributing to innovation in classroom assessment, and broad-based assessment in the direction of assessing student competencies; developing independent thinking, creativity in learning of students and the ability to apply the knowledge learned to solve practical problems; (3) actively preparing for the educational reform roadmap, changing the new curriculum and curriculum towards learner capacity development.

For Vietnam, after the data was published, some researchers also exploited PISA Vietnam data from a number of different research angles. Nguyen (2013) researched the impact of PISA on the education system of other countries, thereby analyzing opportunities and lessons for Vietnamese education when participating in PISA, such as: (1) Understanding and accessing international standards on education; (2) Learn from the educational experiences of countries that have achieved high achievements through PISA exams; (3) Based on PISA's educational assessment experience, a separate assessment system can be developed for Vietnam; (4) Participate in international cooperation on education. Vu (2020) used data from the Programme for International Student Assessment (PISA) in 2015 to test the hypothesis in the research framework on the influence of demographic and family characteristics on the academic performance of Vietnamese students and students in some East Asian countries. The results suggest that among demographic characteristics, not attending kindergarten, attending kindergarten for less than a year, or attending elementary school with a delay in age can all reduce secondary school performance. Tang et al. (2019) using a linear regression analysis method, the results showed that regular use of query-based teaching by teachers will increase students' scientific achievement. The study also makes a number of recommendations based on research results to improve the quality of science teaching and students' science literacy.

However, there are still many issues related to PISA data mining as well as many research issues that remain unexplored, especially those related to the factors affecting the corresponding competencies in PISA assessment and some modern statistical techniques have not been used to analyze this data. This study explores a number of factors influencing high school students' science literacy by harnessing PISA 2015 data to better understand how students are thinking about science as well as to examine the relationship between science literacy and students' internal factors.

2. Research results

2.1. Research Framework

Based on the data and an overview of previous research models, the following observed and latent variables in the PISA 2015 questionnaire data of Vietnamese students were selected for

inclusion in the Analytical Framework for this task.

+ Science literacy: It is noted that the science literacy scores were calculated using a two-parameter logistic model, a generalisation of the Rasch model. One of the benefits of using this model is that it ensures the results wouldn't depend on the particular group of examinees. The ability estimates were transformed to scores on the scale with a mean of 500 and a standard deviation of 100.

+ Variables that assess students' school learning: Includes observational variables related to students' perceptions of their science teacher.

+ Variables that assess students' views on science as well as science learning: For this area, observational variables that assess students' Science interests, the Usefulness of Science and their Epistemological Beliefs about Science are used.

Through these variables, a proposed framework on factors influencing students' science literacy is shown in Figure 1. In this model, many hypotheses have been posed about the influence of latent variables on students' characteristics and perceptions of students' science literacy. In addition, the mission also went to study the relationships between groups of latent variables in terms of students' characteristics.

In particular, the following hypotheses are posed:

(i) Vietnamese students' Science Interest and the Usefulness of Science positively and directly affect the science literacy of 15-year-old students;

(ii) The student's Epistemological Belief about Science has a positive and indirect effect on the student's science literacy through the student's students' Science Interest and the Usefulness of Science;

(iii) Students' perceptions of science teachers have a positive and indirect effect on students' science literacy through students' Science Interest and the Usefulness of Science.

Based on the overall PISA 2015 dataset, student data is extracted based on Vietnamese identifiers. For the data to study the influencing factors, the data is also taken from the overall PISA questionnaire data file. The data includes 5,826 15-year-old students (52.2% male and 47.8% female) who participated in the Programme for International Student Assessment (PISA) in 2015.

2.2. Descriptive statistics

Table 1 provides descriptive statistical information about the important variables for this study.

Based on the results in the table above, it can be seen that the majority of students participating in the PISA assessment program are very interested in science; the majority of them think science is useful and have a positive epistemological belief in science. Specifically, it can be seen that over 84% of students think that they enjoy learning new things about extended science, enjoy reading about extended science, and find it interesting to

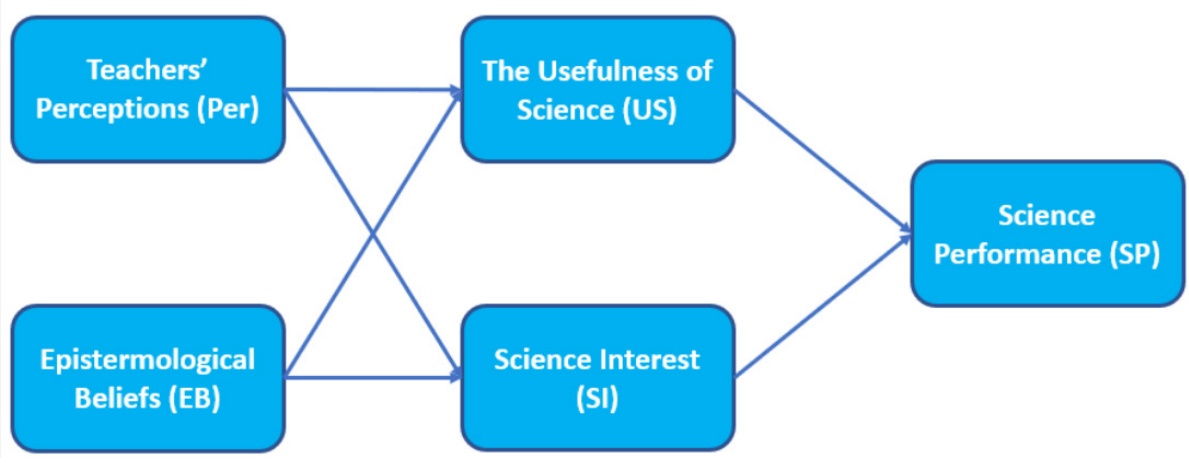

Figure 1. Vietnam's PISA 2015 data analytics framework

Table 1. Statistics of observed variables that assess the internal factors of the students

No	Statement	Student Choice Rate				Factor loading
		Strongly disagree	Disagree	Agree	Strongly agree	
Science Interest (SI)						
SI1	I often find it interesting to study extended science topics	3.4	7.2	64.3	25.2	0.746
SI2	I love reading about extended science	2.8	10.5	64.6	22	0.775
SI3	I have fun working on extended scientific topics	2.7	9.5	63.9	23.9	0.766
SI4	I like to explore new knowledge about expanded science	2.7	13.1	58.4	25.8	0.728
SI5	I am interested in learning about extended science	2.9	9.6	63.3	24.3	0.778
Usefulness of Science (US)						
US1	The effort to study science is helpful because it will help you in the work you want to do in the future.	3.9	4.8	59.2	32.1	0.729
US2	What you learn from Science subjects is important because you need that knowledge for the work you want to do in the future.	3.8	8	61	27.3	0.779
US3	Studying science is helpful because what you learn boosts your career prospects	4.2	10.2	59.5	26.1	0.75
US4	Many of the things I learned from Science subjects will help me find a job.	4.8	22.9	55.6	16.7	0.556
Epistemological Beliefs in Science						
EB1	A good method to know if something is true is to do experiments	4.6	13.2	65.1	17	0.561
EB2	Ideas in extended science change from time to time	2.7	15.5	74.2	7.7	0.456
EB3	Good answers are based on the evidence of various experiments.	4	7.3	58.9	29.7	0.656
EB4	It is better to conduct more experiments than just one to be sure of your findings.	5	12.2	49	33.9	0.621
EB5	Sometimes, scientists in expansive science change their minds about what is true in science.	4.4	17.6	65.6	12.3	0.428
EB6	The ideas in the science books of the extended sciences sometimes change	3.8	17.9	67.5	10.8	0.399
Teacher's Concern for Students (Per1)						
SPer1	Teachers show interest in every student's learning.	47.8	36.1	14.3	1.8	0.64
SPer2	Teachers provide extra help when students need it.	55.3	35.1	8.7	0.9	0.659
SPer3	Teachers help students in their learning.	41.6	34.9	18	5.5	0.518

No	Statement	Student Choice Rate				Factor loading
		Strongly disagree	Disagree	Agree	Strongly agree	
SPer4	The teacher continues to teach until the student understands.	45.9	35.7	16.3	2.1	0.611
SPer5	Teachers give students the opportunity to voice their opinions.	57.9	33.8	7.5	0.8	0.576
Science Teachers' Teaching Organization (Per2)						
SPer6	The teacher explains scientific ideas.	16.3	32.7	45.7	5.3	0.586
SPer7	The whole class discusses with the teacher	10.1	23.9	54.9	11	0.642
SPer8	The teacher discusses our questions	12.5	29.4	47.2	10.8	0.655
SPer9	The teacher presents an idea	21.7	36.5	36.8	5	0.619
Science Teacher Feedback (Per3)						
SPer10	The teacher showed me how I was learning this subject	10.9	26	51.8	11.4	0.534
SPer11	The teacher gives feedback on my strengths in this Science subject.	7.8	19.7	51.6	20.9	0.599
SPer12	The teacher showed me what areas I could progress in	9.4	20.7	48.8	21.1	0.662
SPer13	My teacher showed me how to improve my performance.	23.3	36.4	35.4	5	0.689
SPer14	My teacher advised me on how to achieve my learning goals.	26.9	34.4	34.4	4.3	0.638

learn expanded science topics. In addition, more than 91% of students in the sample said that the effort to learn science subjects was useful because it would help them in the work they wanted to do in the future, and over 85% of students said that what they learned from Science subjects was important because they needed that knowledge for work. In addition, the majority of students in the sample (over 80%) said that a good way to know if something is true is to do experiments, that good answers are based on the evidence of various experiments, and that more experiments should be conducted than just one to be sure of their findings.

However, there is still a small portion of students (less than 15%) who have a negative attitude toward science and show no interest in studying science. Through the process of sifting through the data, it can be seen that students in this group also tend to think that studying science is not useful for life, as well as having inconsistent epistemological beliefs about science.

Through the above results, it can also be seen that the majority of students assumed that the teacher was interested in the students' learning. Over 90% of students said their teachers provided extra support when students needed it and gave them the opportunity to voice their opinions in a variety of ways in classroom lessons. Over 80% of students reported that their teacher continued to teach until they understood the new knowledge in many lessons. In addition, PISA data showed that about 20% of students in the sample said that their science teacher never gave feedback on their strengths in science or showed them where they could improve. More than 10% of students said their science teacher never showed them how they were doing in the subject.

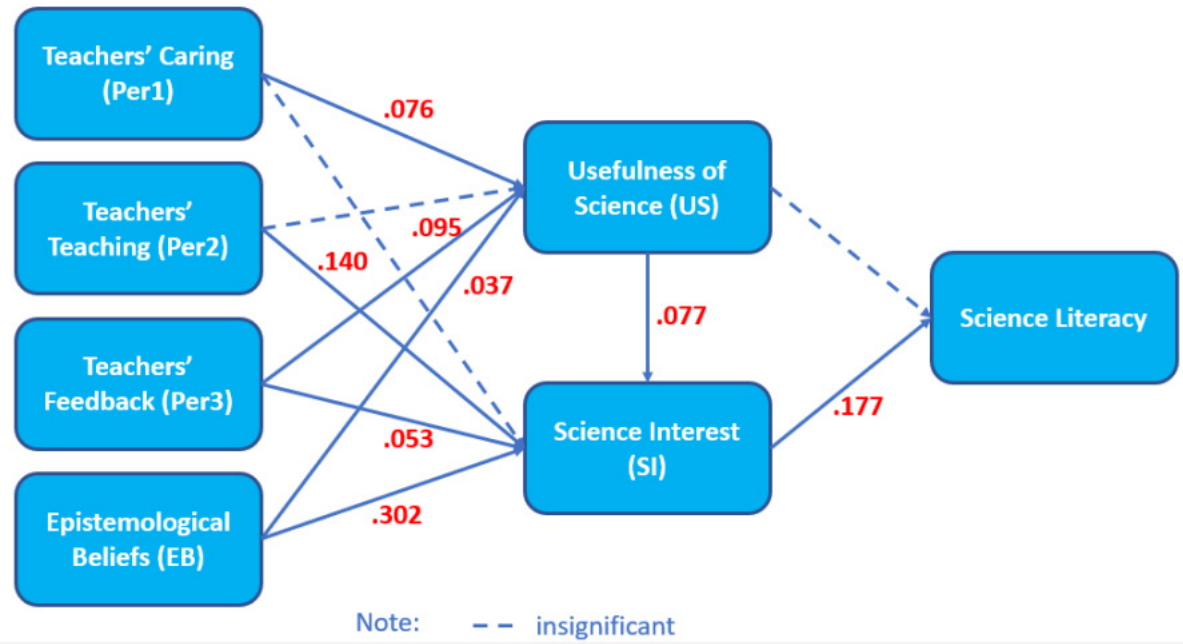

Figure 2. Results of testing theoretical models through data of PISA Vietnam 2015

2.3. Factors influence the science literacy of Vietnamese students

Figure 2 depicts the SEM model's results on the influence of factors related to students on their Science literacy. In terms of statistical indicators of the model, it can be seen that PISA Vietnam 2015 data has provided indicators of good suitability with the selected model. Specifically, the fit indicators from the model are [RMSEA=0.037; CFI = 0.931: TLI = 0.923; SRMR = 0.032]. In addition, from this analysis model, it can be seen that the load factors of each question in each hidden variable of interest are 0.4 or higher, as shown in the last column of Table 1.

From the above model, it can be seen that all three internal factors of the student including Science Interest (SI), Usefulness of Science (US) and Epistemological Beliefs (EB), positively affect science literacy. In particular, it can be seen that the Science Interest (SI) factor directly and positively affects science literacy with an impact factor through the SEM model of 0.177. This explains that for students in the PISA assessment, the more interested they are in science, the higher the results of science literacy. These results are consistent with a number of other studies around the world on the relationship between general interest in learning and academic achievement, as well as specifically for the field of science learning.

One of the interesting findings for PISA Vietnam's student data in 2015 is the view that the Usefulness of Science does not directly affect science literacy due to its lack of statistical significance. This result is inconsistent with some studies in a sample of students in some other countries who have found a strong link between this factor and science literacy. However, the analysis shows that the Usefulness of Science has an indirect effect on students' science literacy through Science Interest, and this is a positive influence. Through the results from the analytical model, it can be seen that the more students see the Usefulness of Science, the more interested they are in science and from there, their science literacy will grow. The results regarding the relationship between the Usefulness of Science and Science Interest found in this study are also consistent with some previous studies of high school students in several countries around the world.

From the above model, it can be seen that Epistemological Beliefs about Science also have a positive and indirect effect on students' science literacy through the Usefulness of Science

factor and the Science Interest factor. It can be seen that the influence of the factor related to Epistemological Beliefs about Science on the factor of Science Interest is quite large (with an impact factor from the SEM model of 0.302). This explains that, for students, there is a growing belief that the results obtained in science must be based on the evidence of many experiments. This is one of the key findings of this study through PISA data. The factor associated with Epistemological Beliefs about Science also influences the Usefulness of Science factor and this influence is positive. This demonstrates that when students have a positive and flexible belief in the knowledge and nature of science, the more they see its usefulness. However, with Vietnam's PISA 2015 data in this study, the impact factor from the SEM model is very small.

With the SEM model, the results of the data analysis indicate that all three good requirements relate to teachers, including (1) Teacher's attention to students (Per1); (2) Science Teachers' Teaching Organization (Per2); and (3) Science Teacher Feedback (Per3) both indirectly and positively affect students' science literacy.

3. Conclusions

The present research examines a number of factors affecting the science literacy of Vietnamese students through data from Vietnamese students participating in the PISA 2015 International Student Assessment Program. It can be seen that with the selected model, all factors have a positive influence on students' scientific achievement. Specifically, students' interest in learning science positively and directly affects the Science capacity of 15-year-old students in Vietnam. In addition, the concept of the usefulness of science to life positively and indirectly affects Science capacity through the interest factor of 15-year-old students in Vietnam. In addition, students' perceived beliefs in science have a positive and indirect effect on students' Science literacy through their interest in learning science and their conception of the usefulness of science to life. Finally, students' perceptions of science teachers have a positive and indirect effect on students' Science literacy through students' interest in learning Science and Conception of Science's usefulness in life.

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