Measuring the knowledge about science in student's learning achievement

Munkhsaikhan Yadamjav[1], Enkhlut Chuluunkhuu[2], Bulgamaa Battsogt[3,*], Burmaa Banzragch[4]

[1] *School of Mathematics and Natural Sciences, Mongolian National University of Education, Mongolia*
[2] *School of Arts and Sciences, National University of Mongolia, Mongolia*
[3] *Baigali Ekh High School and Ecology Education Center Under National University of Mongolia, Mongolia*
[4] *Department of Physics, School of Arts and Sciences, National University of Mongolia, Mongolia*

Since 2000, The Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) has been aiming to provide understanding of students' learning achievement within the wider educational community [2]. In order to achieve the goal, they have defined that scientific literacy consists of "Knowledge of science" and "Knowledge about science". The latter refers to the knowledge of the skills (scientific enquiry) and the goals (scientific explanation) of science. This article introduces how we used probability and statistics to assess the knowledge in order to provide a general direction for policy makers in educational systems.

1. INTRODUCTION

Since 2000, The Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) aims to provide understanding of students' learning achievement and encourage discussion about assessment within the wider educational community. In order to achieve the goal, they have focused on major domains, such as mathematics, science, reading etc … Among these, they have defined that scientific literacy [2] consists of two knowledge: knowledge of science and knowledge about science (scientific enquiry). First, scientific enquiry referring to the knowledge of the skills, has six skills of science:

- Origin (e.g. curiosity, scientific questions) (denoted "S11" in the results section)
- Purpose (e.g. to produce evidence that helps answer scientific questions, current ideas/models/theories guide enquiries) (denoted "S12")
- Experiments (e.g. different questions suggest different scientific investigations, design) (denoted "S13")
- Data (e.g. quantitative [measurements], qualitative [observations]) (denoted "S14")
- Measurement (e.g. inherent uncertainty, replicability, variation, accuracy/precision in equipment and procedures) (denoted "S15")
- Characteristics of results (e.g. empirical, tentative, testable, falsifiable, self-correcting), (denoted "S16")

second, scientific explanation referring to the goals of science, has four skills of science,

- Types (e.g. hypothesis, theory, model, scientific law) (denoted "S21"),
- Formation (e.g. existing knowledge and new evidence, creativity and imagination, logic) (denoted "S22"),
- Rules (e.g. logically consistent, based on evidence, based on historical and current knowledge) (denoted "S23"),
- Outcomes (e.g. new knowledge, new methods, new technologies, new investigations) (denoted "S24").

According to PISA, student's attitude towards science is another important key factor which defines science literacy [2]. However, what we tried to measure in this article is how knowledge about science influences learning achievement of students [3], especially the students who are very interested in physics subject with updated curriculum [6]. In this way, we would be able to measure which skills of science are well taught, and which skills of science need update to be taught in a better way.

2. METHODOLOGY

2.1. Participants and procedure. We took a survey to collect necessary data for the research [6] using strict and precise method of PISA survey [2]. Also, in order to apply the precise method, we needed to adjust the core curriculum for primary [4] and secondary [5] education to frame of PISA survey. So, students who are fairly engaged in updated physics courses had a slightly different curriculum.

* Electronic address: bulgamaa@num.edu.mn

The survey covered 1652 students of different regions: 9 districts in Ulaanbaatar city and 21 aimags in the rural areas. The students who are fairly interested in physics subject and the students who are engaged in updated physics courses were also involved in the survey.

2.2. Measures and equations. *Correlation coefficients.* To measure skills of the students engaged in physics subject, the students need ten different skills, mentioned in the introduction; six skills of scientific enquiry and four of scientific explanation. We need to know whether these skills are distinct from each other or have different influence in student's learning achievement. So we can make calculation of their correlation coefficient1 in order to see how strong their relationship is. The stronger the relationship is the more similar the skills are, the weaker the relationship is the more different the skills are.

$$\rho = \frac{E\left((X-\mu_X)(Y-\mu_Y)\right)}{\sqrt{E\left((X-\mu_X)^2\right)E\left((Y-\mu_Y)^2\right)}}$$

Equation (2.2.1). Correlation coefficient.

This equation above shows the relationship between two skills, X and Y. Here, the μ_x is the average of X, and μ_y is the average of Y.

2.2 Measures and equations. Mean of the score of each survey collected for each skill represents the students' learning in that skill. In order to measure student's learning, we took the mean of observations as Post-test in g coefficient10. G-coefficient fall into 3 categories10: low (0-0.3), medium (0.3-0.7), high (0.7-1.0)

$$< g > = \frac{(\text{Post-test} - \text{Pre-test})}{(100\% - \text{Pre-test})}\ .$$

This G-coefficient calculates student's growth because it includes Pre-test score. But what we were trying in this research is learning achievement, not growth. Moreover, the purpose of the research is about all students, not individuals and the result is relative, so we may take no account for "Pre-test" equaling to 0. In this way, we can use the means of the score as a direct factor for measuring the student's learning for the skill and may use the 3 categories.

Standard deviations refer to whether students are learning the skills differently from each other. For the standard deviations of observations, we divide it into 2 categories: first, with five highest standard deviations and second, with five lowest standard deviations so that we may assume that relatively high standard deviation means that students' skills differ from one another.

When we compare means and standard deviation of these different skills, we can conclude 6 different results for each skill

- Mean-low (0.0-0.3) std.dev-relatively low: bad performance, similar learning among students
- Mean-low (0.0-0.3) std.dev-relatively high: bad performance, relatively different learning among students
- Mean-medium (0.3-0.7) std.dev-relatively low: enough performance, relatively similar learning among students
- Mean-medium (0.3-0.7) std.dev-relatively high: enough performance, relatively different learning among students
- Mean-high (0.7-1.0) std.dev-relatively low: good performance, relatively similar learning among students
- Mean-high (0.7-1.0) std.dev-relatively high: good performance, relatively different learning among students.

The skills having relatively low standard deviation mean that students have similar learning. However, for the skills having relatively high standard deviation, we are not sure to give exact explanation yet. In order to find the explanation, we need further research depending on relevant factors.

3. RESULTS

When we try to calculate the correlation coefficients of skills, every coefficient is estimated individually by using Equation 2.2.1. And the table below shows the results:

3.1. Correlation coefficients of skills.

As the table shows, all correlation coefficients do not exceed 0.7 and most of the coefficients do not exceed 0.3, especially correlations between skills of science enquiry, meaning they are not correlated each other.

TABLE 3.1.1. Correlation coefficients of the skills.

Correlation coefficient	S11	S12	S13	S14	S15	S16	S21	S22	S23	S24
S11	1.000									
S12	0.202	1.000								
S13	0.156	0.177	1.000							
S14	0.197	0.166	0.147	1.000						
S15	0.205	0.246	0.247	0.236	1.000					
S16	0.130	0.111	0.144	0.149	0.202	1.000				
S21	0.221	0.280	0.302	0.322	0.402	0.167	1.000			
S22	0.230	0.202	0.268	0.262	0.275	0.096	0.390	1.000		
S23	0.227	0.246	0.232	0.234	0.299	0.209	0.392	0.259	1.000	
S24	0.167	0.236	0.275	0.244	0.371	0.183	0.520	0.285	0.320	1.000

In other words, they are distinct skills that influence students' learning in different ways.

3.2. Means and standard deviations.

TABLE 3.2.1 Main statistics of the skills.

	S11	S12	S13	S14	S15	S16	S21	S22	S23	S24
Mean	0.736	0.308	0.280	0.503	0.332	0.310	0.410	0.409	0.326	0.394
Median	1.000	0.333	0.250	0.500	0.333	0.278	0.375	0.000	0.317	0.333
Max	1.000	1.000	0.750	1.000	0.833	0.833	0.875	1.000	0.867	1.000
Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Std.Dev	0.420	0.332	0.184	0.481	0.192	0.158	0.266	0.460	0.171	0.333

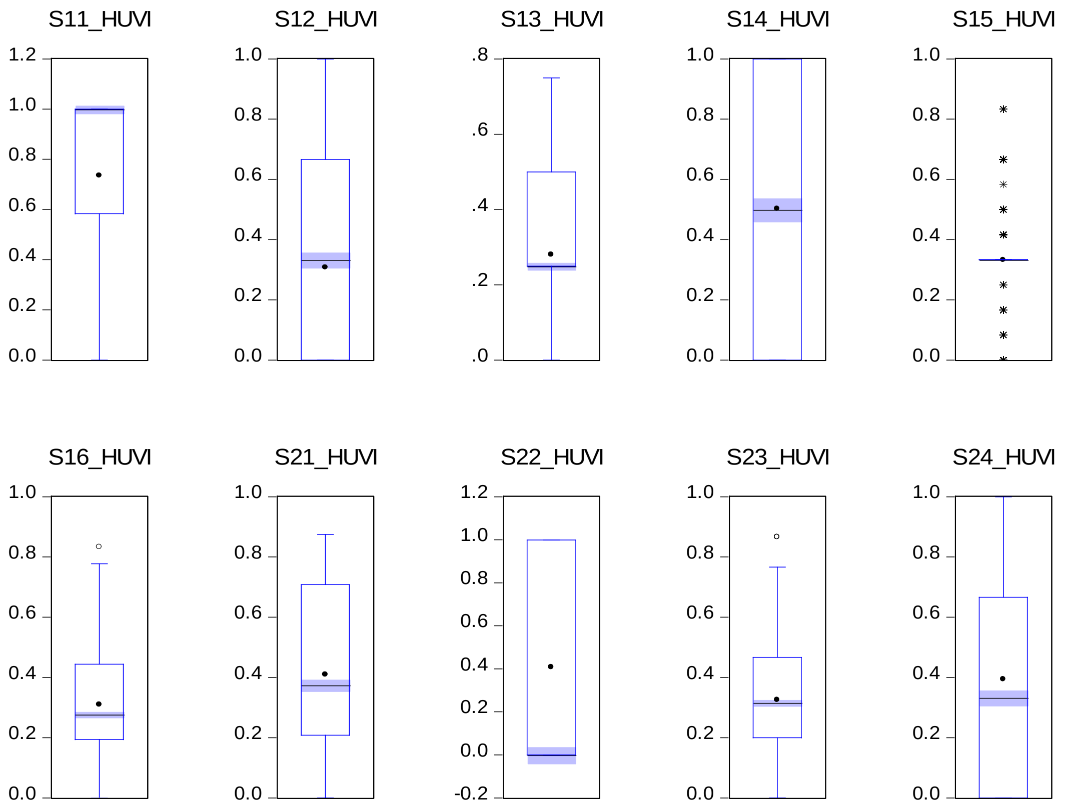

Figure 3.1. Boxplots of the skills.

From the table and boxplots which shows the mean, first and third quartiles, skill “Origin” falls into high category, skill “Experiment” falls into low category, and rest of the skills fall into medium mean. Also, for the standard deviation, skills “Origin”, “Purpose”, “Data”, “Formation”, “Outcomes” have relatively high standard deviation, and rest of the skills have relatively low standard deviation.

4. CONCLUSIONS

Since all of the correlation coefficients do not exceed 0.7 and most of them do not exceed 0.3, we can assume these skills are different from each other. From this point, we may conclude that these skills are distinct from each other and impact students' learning achievement in different ways.

For the students in the 8th grade who are studying on the new “core “curriculum, the skill of Origin is shaped quite well whereas the skill of Experiments shows lower level. The rest of the skills are in the median level. It can be noticed that the skills of Origin, Purpose, Data, Formation and Outcomes are at relatively different levels throughout Mongolia.

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