Journal of Science Education Vol.23 n. 2 2022

Journal of Science Education

ISSN 0124-5481

A study of Chinese ninth grade students' ability to make scientific arguments in physics

Zijuan Yin[a], Jing He[b], Di Yin[c], Xiaofeng Hu[d], Shizhen Yan[e], Jiayue Chen[f]

[a] Normal College & School of Teacher Education, Qingdao University, Qingdao 266071, P.R. China
[b] Peking University Affiliated High School, Beijing 100190, P.R. China
[c] Guanzhuang Branch of Beijing Eighty Middle School, Beijing 100024, P.R. China
[d] Beijing Bayi School, Beijing 100000, P.R. China
[e] Zhejiang Wenhai Middle School, Hangzhou 310018, P.R. China
[f] Shanghai Private Wenqi Middle School, Shanghai 200240, P.R. China

ARTICLEINFO

Keywords:
scientific argumentation competence
Rasch test
tool development
competence performance

ABSTRACT

This study defines the connotation as well as the structural elements of scientific argumentative ability in the context of physics, constructs a scientific argumentative ability assessment tool, and performs a Rasch quality test as well as an analysis of the assessment results. The study shows that the test instrument has high reliability and credibility, that students' scientific argumentation skills are weak, and that there is a correlation between students' scientific argumentation skills and their academic performance in physics, but not with gender, and makes relevant pedagogical recommendations for the development of scientific argumentation skills.

The core literacy frameworks of countries, regions and organisations around the world emphasise collaboration, communication, language, problem-solving and critical thinking skills, which are also five competencies that must be possessed in the scientific argumentation process (Han.2019). Scientific argumentation is a higher-order thinking skill that points to rational thinking and is an important component of core scientific literacy. According to the Organisation for International Economic Cooperation (OECD), scientific literacy is the ability to use scientific knowledge to identify issues and make evidence-based conclusions in order to make sense of and decisions about the natural world and the changes to it through human activity（Zhou，2017）. Scientific logic is formed and applied to scientific understanding activities as a process of moving from the concrete to the abstract and then from the abstract to the concrete, through concepts, judgements and reasoning, reproducing the essence of objective things in thinking and truly reflecting the laws of motion of objective things（Zhou，2017）. Scientific logic is a method of research based on experimentation through generalisation, abstraction and reasoning to arrive at a law, the essence of which is scientific thinking, the specific application of inductive and deductive methods in the field of science; it is the ability to question, criticise, test and amend different views and conclusions based on factual evidence and scientific reasoning, and then put forward creative ideas, mainly including scientific reasoning, scientific analysis and Scientific argumentation and other core thinking skills. Argumentation is a central topic in scientific research and is at the core of learning science. 2022 edition of the Physics Curriculum also emphasises the ability to argue scientifically as an important component of students' core literacy, and scientific argumentation is not only an important tool for learning scientific concepts, but also a science education activity based on argumentation that can promote students' understanding of scientific concepts and their ability to reason and reflect critically (Ministry of Education,2022).

1 Basic connotations and structural elements of scientific argumentative capacity

Scientific argumentation is the process of using the 'rules' agreed by the scientific community to explain scientific and technological phenomena and to draw scientific conclusions, based on evidence-based thinking, on evidence and logic, and on the need for this evidence to stand up to scrutiny and to be discerned as true or false. Scientific argumentation involves both critical and analytical reasoning, and its focus is on the logic of argumentation. Scientific argumentation is a complex and comprehensive practical activity in which the community collects evidence around a topic using scientific methods, uses certain argumentation to explain and evaluate the relevance of its own evidence (or views) and that of others, and through the sharing and exchange of ideas, eventually reaches a conclusion acceptable to the community. Taking into account national and international research as well as the 2022 edition of the Physics Curriculum Standards, this study defines scientific argumentation skills as the process of argumentation in which students formulate their own views or claims in a physics problem situation, reason validly based on factual evidence or theoretical grounds, and logically evaluate and refute the views of others. This study therefore classifies the basic structural elements of scientific argumentation as: presenting a point of view, factual evidence and theoretical basis, and reasoning and rebuttal. The ideas are drawn from Osborne's (2016) progression of learning scientific argumentation, which emphasises that students' ability to formulate and identify ideas is the foundation level stage and the cornerstone of constructing arguments . Factual evidence and theoretical foundations, reasoning and rebuttal are all derived from Chen Ying's (2016) framework for assessing scientific argumentation , which emphasises the ability to obtain evidence from research questions or data sources and the ability to invoke knowledge of relevant integrated scientific concepts; and focuses on the ability to reason in establishing a scientifically logical relationship between evidence and viewpoint and the ability to rebut the opponent's viewpoint, evidence, and the logically adequate and reasonable rebuttal of the reasoning process.

Accepted 1 October 2022, Available online 10 July 2023

2 Research Methodology

2.1 Research tools and evaluation gauges

Evaluation is effective feedback on teaching and learning, and evaluation of argumentation is central to the logic of argumentation. There are three ways of evaluating scientific argumentation skills in national and international research: oral argumentation, written argumentation and computer-based assessment. Oral arguments tend to be more dependent on the context of the problem and the logic of the discourse. This approach is more often found in science education in science classrooms, where the teacher throws out an argumentative topic, mostly a scientific situation or a social science issue, and students use evidence and arguments based on the actual situation to refute it. It also makes assessment very difficult. Computer-based assessment requires students to record their statements on an assessment platform and then evaluate them, which is different from traditional face-to-face discussions and better able to take advantage of individual strengths, but the required assessment environment, development and maintenance costs, and students' ability to operate computers are relatively high, making it difficult to spread widely in the teaching and learning process. Written argumentation is a more operational way of assessing students' argumentation, and can provide a more complete picture of their argumentation process. It is more credible to assess students' argumentation skills by means of written writing or related ability tests, but it also requires students' written expression skills and students' mastery of relevant basic knowledge. This approach is currently a more credible and widely used approach, both nationally and internationally, so this study developed a set of task-based questions to measure students' development of scientific argumentation skills in the context of the physics discipline.

The task questions of this research tool are mainly designed based on the core knowledge of the physics subject and the basic elements of scientific argumentation ability. The problem contexts are carried by the knowledge of electricity that students have already learnt and do not involve the construction of new knowledge, which can reduce the influence of the control variables on the students' ability to measure scientific argumentation. The task questions are divided into three contextual topics, and due to space limitations, only the task question design for Context 1 is shown here, with the specific topics designed as follows:

Scenario 1: Ming is going to make a string of small coloured lights for use during the festive season. He has found some incandescent bulbs, all of which have the same voltage rating but obscure power ratings. Ming connects them to a 12V supply as shown in Figure 1 and finds that the small bulbs are brighter or darker in different ways.

Xiaohong thinks: the lamp with the lower wattage rating in this circuit is brighter than the lamp with the higher wattage rating;

Xiao Ming thinks: The lamp with the higher wattage rating in this circuit is brighter than the lamp with the lower wattage rating.

1. Who do you think is correct, Xiao Ming or Xiao Hong? Use what you have learnt to deduce and prove your point of view.

2. They prove their point of view again by experiment. The diagram on the right shows the experimental circuit they designed together. Experimental equipment: a bulb L1 with a supply voltage of 2V, labelled '2V 1W' and a bulb L2 labelled '2V 4W', a switch and some wires. Can this circuit diagram explain the phenomenon in the circuit of the small coloured lamp? If not, state the reason for the error and describe how it can be corrected.

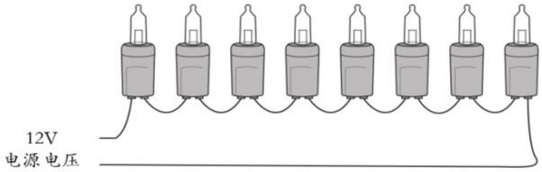

Figure 1 Scenario 1: Small light bulbs in series

Subsequently, corresponding assessment scales were developed based on the basic elements of physical problem situations and scientific argumentation skills, with the following specific scales for Scenario 1:

2.2 Rasch tool quality check

2.2.1 Reliability of assessment tool raters

The evaluation process of the test tool is an important bridge to guarantee the overall test results. It is therefore particularly important to ensure the reliability of the test instrument and the reliability of the assessment must be guaranteed. Firstly, the reliability assurance of this study was based on Chen Ying's research on the elements of scientific argumentation ability, under the guidance of a number of front-line teachers, the electrical knowledge points of junior physics were selected as the topics, and the open experiment design questions were used as the topic types, and the corresponding gauges were formulated based on the level of physical scientific argumentation ability, and front-line physics backbone teachers were invited to propose modifications to the test questions. Students familiar with the selection and marking requirements of the pre-test questions were pre-coded once, the marking scale was adjusted again for the second pre-code based on the first pre-code marking, and three pre-codes were conducted after agreement between the three reliability checkers and the expert scholars and front-line teachers, until the mutual agreement between the three reliability checkers reached 0.8 or more before independent coding began and for two-by-two cross-code marking was completed After this, the three agreed on the final coding scores to ensure the reliability of the scores.

2.2.2. Rasch quality inspection

In order to examine the quality of the assessment instrument, this study used Rasch analysis of the assessment instrument using Winsteps software to examine the match between the test questions and students' ability levels. Firstly, from the analysis of the overall quality of the scientific argumentation assessment tool, the Measure value of the test subjects indicates the average ability of 1319 students, and the ideal value is 0, which indicates that the students' assessment ability level is at an intermediate level, and the Measure value of the test subjects is -1.27 from the Rasch analysis, which indicates that the average ability level of the students is low, which also indicates that the students' scientific argumentation ability is relatively weak. The ideal value of the Rasch model is 2, which is greater than 2, indicating a greater degree of differentiation, and the opposite is worse. Separation is 3.86, which means that the differentiation of the test items is also relatively good, and the Items Reliability of the test items is 0.94. This indicates that the reliability of the test items is relatively high. Infit and Outfit are the goodness-of-fit indicators of the Rasch model. The closer the MNSQ of Infit and Outfit is to 1, the better the fit is. This shows that the fit, difficulty, differentiation and reliability of the test items are all in line with the requirements and the overall quality is relatively high. This requires a unidimensionality test to be conducted on each item of the test to ensure that whether the test items are testing and analysing a certain trait or ability of the students and removing the influence of other irrelevant factors, in the standard residual plot, when the unidimensionality is between [-4,+4] indicates that the unidimensionality is good and This is consistent with the Rasch model.The Rasch analysis of the residual plots shows that the unidimensionality of the test items are all in the acceptable range of -0.4 to +0.4, indicating that these test items are not disturbed by other factors and are only influenced by certain abilities, which can ensure the accuracy of the study. In order to further analyse the relationship between the test items and the test items, between the test items and the students, and between the students and the students, this study also used the Rasch model to analyse the distribution state of its Waite chart, which can clearly clarify the distribution trend of students' ability level and the average difficulty of the test items, each test item has a certain number of students corresponding to indicate that the test items have higher reliability and validity, the difficulty of the test items is at When the difficulty level of the test items is at a medium level, students of medium and high ability can do it, while when the difficulty level of the test items is at a low level, it does not differentiate well between students of high and low ability, and students of all levels can do it, when the difficulty level of the test items is at a high level, students of medium and low ability cannot differentiate, and students of high ability sometimes lose confidence because the difficulty level of the test items is too high, resulting in Students with high levels of ability do not perform well. The Rasch model Wyatt chart shows that the majority of the test items hover around the average level, suggesting that the test items are of moderate difficulty, while some students' ability levels are distributed below the average, suggesting that this group of students is weak in scientific argumentation, while a smaller number of students are found in the above-average area, suggesting that these students are still strong in scientific argumentation. It is worth exploring these high level students in depth. In conclusion, this set of tests is generally consistent with the Rasch model and has a high degree of reliability in measuring students' scientific argumentation skills.

A total of 1,319 Year 9 students from four regions, namely Beijing, Shanghai, Hangzhou and Shandong, were selected for this study. 1,390 questionnaires were distributed and 1,319 valid questionnaires were returned, ensuring that all students from the selected schools had learned all the knowledge contained in the task questions and met the requirements of the test subjects.

3 Research findings

Table 1 Test item specific evaluation gauges

Level	Making a point	Factual evidence and theoretical foundations	Reasoning and Refutation
Level 3	Consider Hong's view correct and explanation adequate	Use the following five pieces of evidence: Factual evidence. 1. the bulbs have the same voltage rating 2. the small coloured lights are in a series circuit Theoretical basis: 1.$P=U^2/R$ 2. Equal currents 3.$P=I^2R$	On the basis of the rebuttal of Xiaoming's views, a scientific logical chain is established between the factual evidence and the views, and the factual evidence, theoretical basis or reasoning process of Xiaoming can be rebutted, and the factual evidence used for the rebuttal is sufficient, the theoretical basis is sound and the reasoning is logical
Level 2	Considered Hong's view correct, inadequate explanation, no explanation given or wrong explanation	A total of three to four factual evidence and theoretical grounds are presented	On the basis of refuting Xiaoming's view, a scientific logical relationship is established between the factual evidence and the view, and although there is a refutation of Xiaoming's factual evidence, theoretical basis or reasoning process, the refutation is flawed
Level 1	Believed that Ming was correct or did not express a view	One or two factual and theoretical bases are presented or incorrect/unrelated bases are used	Reasoning process only, no refutation of Xiaoming's view / Refutation of Xiaoming's view only, no reasoning process

3.1 Overall expressive analysis of scientific argumentation capacity

In order to understand the current status of the development of the scientific argumentation ability of the nine students, descriptive statistical analysis was done on the performance of all the subjects on different dimensions of scientific argumentation ability, and the results were shown in Table 2. In order to further analyse the distribution of students' levels in each dimension, the test data were made to come out with the percentage statistics, and the results are shown in Figure 2.

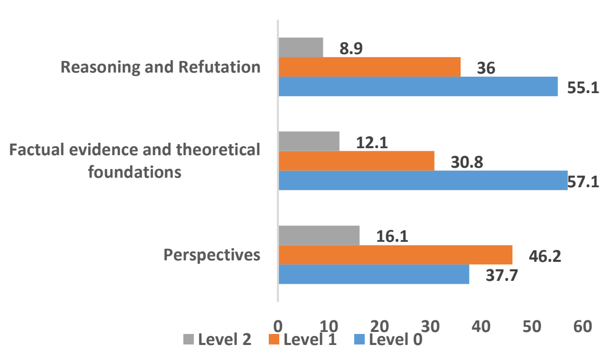

Figure 2 Percentage of student score levels for each dimension of scientific argumentative skills

In statistics, according to Kline, if the skewness takes a value between [-3.00, +3.00] and the kurtosis takes a value between [-10, +10], then the measured data conforms to an approximately normal distribution(Zheng,2019). From the data analysed in the descriptive statistics above, we can see that the kurtosis and skewness of the opinion, factual basis and theoretical foundation, reasoning and refutation and scientific argument scores, where the values of kurtosis are between -0.216 and 0.261 and the values of skewness are between 0.385 and 0.723, are clearly consistent with a normal distribution for both kurtosis and skewness. Therefore, the total scores and the performance of the dimensions of scientific argumentative skills of Grade 9 students obeyed a skew-normal distribution.

From the data in Table 2 above, it can be seen that the scores of Grade 9 students' scientific argumentation ability in viewpoint, factual basis and theoretical foundation, reasoning and refutation and scientific argument performance are 0.29462, 0.20602, 0.20195 and 0.23392 respectively. it can be seen that the scores of the three dimensions of viewpoint, factual basis and theoretical foundation and reasoning and refutation are gradually decreasing, reasoning and refutation stage is also more difficult to master and opinion is the easiest to judge, which indicates that the higher the level of thinking, the lower the score rate and the lower the overall score rate for scientific argumentative skills, indicating that students' performance in scientific argumentative skills is generally low.

As can be seen from Figure 1, the level scores of the sample students in the opinion dimension are still relatively high compared to the other two dimensions, with Level 2 accounting for 16.1%, while the Level 2 scores of factual evidence and theoretical foundations and reasoning and rebuttal are 12.1% and 8.9%, and the level score of reasoning and rebuttal dimension is the lowest, with the percentage of reasoning and rebuttal Level 0 reaching 55.1% of the whole sample, which is more than half. This shows that students' practical reasoning and rebuttal skills still need to be strengthened, their search for factual evidence needs to be improved, their basic theoretical knowledge of the subject is not solid enough, and their ability to reason logically and reasonably with facts is also very weak.

3.3 Analysis of the correlation between scientific argumentation skills and physics performance

In order to investigate whether students' scientific argumentation skills are related to their academic performance, the assessment questions were mostly on electricity in physics subjects, so this study correlated the performance in physics electricity with scientific argumentation skills as well as each dimensional ability, and the results are shown in Table 3.

Table 2 Descriptive analysis of scientific argumentation skills and performance levels on each dimension

	Average	Standard error	Standard deviation	Variance	Skewness	Kurtosis	Scoring rate
Perspectives	0.7834	0.01231	0.44700	0.200	0.385	-0.217	0.29462
Factual evidence and theoretical foundations	0.5494	0.01393	0.50597	0.256	0.717	-0.264	0.20602
Reasoning and Refutation	0.5385	0.01256	0.45633	0.208	0.666	-0.025	0.20195
Scientific proof of achievement	0.6238	0.01179	0.42831	0.183	0.723	0.029	0.23392

Table 3 Correlation analysis of scientific argumentation ability and its dimensions with physics performance

	Scientific argumentation	Perspectives	Factual evidence and theoretical foundations	Reasoning and Refutation	Physics scores
Scientific argumentation	1				
Perspectives	0.887**	1			
Factual evidence and theoretical foundations	0.909**	0.668**	1		
Reasoning and Refutation	0.939**	0.777**	0.796**	1	
Physics scores	0.341**	0.249**	0.344**	0.336**	1
** Significant correlation at 0.01 level (two-tailed)					

Table 4 Descriptive analysis of students' scientific argumentation skills by gender

	Gender	Number of cases	Average	Standard Deviation	Standard Mean error
SR	Male	642	.6315	.44774	.01767
	Female	677	.6164	.40922	.01573

Table 5 Independent samples t-test for gender differences in scientific argumentation ability

		F	Significance	t	Freedom	Sig. (bobtail)	Mean Difference	Standard Error Deviation	Difference 95% confidence interval	
									Lower limit	Upper limit
SR	Assuming equal variance	4.719	.030	.639	1317	.523	.01509	.02360	-.03121	.06139
	No assumption of equal variance			.638	1290.753	.524	.01509	.02366	-.03132	.06150

Table 3 shows that the three dimensions of physics performance and scientific argumentation and their scientific argumentation all showed significant positive correlations, with the correlation coefficient between physics performance and scientific argumentation being 0.341 and significant at 0.01, indicating that the higher the subject's performance in physics, the more likely he/she was to show higher scientific argumentation ability, showing a low correlation. The highest correlation between physics scores and the "factual evidence and theoretical basis" dimension of the scientific argument dimension ($r=0.344$, $p<0.01$) was followed by the "reasoning and refutation" dimension ($r=0.336$, $p<0.01$) and the "Opinions" dimension had the lowest correlation ($r=0.249$, $p<0.01$).

3.4 Analysis of the variability of scientific argumentation skills in relation to gender

In order to investigate whether there is an effect of gender-specific students on scientific argumentation ability, this study analysed gender differences in scientific argumentation ability and the related descriptive analysis, the results of which are shown in Tables 4 and 5.

As shown in Table 4, the mean value of scientific argumentation ability for male students was 0.6315 and for female students was 0.6164, the mean value of ability for male students was 0.0151 higher than that of female students, indicating that there was no significant difference in the performance of scientific argumentation ability level between male and female students, indicating that there was no correlation between students' scientific argumentation ability and gender. As shown in Table 5, in the independent samples t-test, the F value was 4.719 with a probability of significance of 0.030, which is less than the significance of 0.05, while the t-value was 0.638 with a two-tailed significance test of 0.524, which is greater than the probability of significance of 0.05, indicating that there is no significant gender difference in scientific argumentation ability between male and female students, and there is no difference in the performance of scientific argumentation logical thinking between male and female students.

4 Summary and recommendations

Based on the above study, the assessment instrument in this study is able to measure students' scientific argumentation skills well, and is consistent with the Rasch model in terms of reliability, difficulty, discrimination, and item fit, and students' performance in scientific argumentation is weak overall, correlated with students' academic performance in physics, but not with gender, and students' reasoning and rebuttal skills are particularly weak.

4.1 Strengthen the development of reasoning and rebuttal and increase the training of logical thinking

Most of the lack of students' reasoning and refutation skills is due to stereotypical thinking. In the physics classroom, the most important thing is the information evidence and the investigation of physical laws, but most of these skills are ignored by teachers, so that formulas or conclusions are given directly. Students' arguments are described in an arbitrary manner, lacking the support of evidence or theoretical foundations, and students are often influenced to pay more attention to the conclusions than to the argumentation The teacher should make this part of the lesson the focus of teaching, chasing students over and over again, from putting forward ideas based on problem situations to finding evidence and theoretical foundations, establishing logical reasoning, making sound scientific rebuttals, summarising ideas these processes, increasing the thinking training of logical reasoning skills, and in each In each section, students are put through these processes to strengthen the development of scientific reasoning and rebuttal skills in order to achieve an increase in overall scientific argumentation skills.

4.2 Develop an awareness of scientific argumentation and clarify the basic meaning of scientific argumentation

The development of scientific argumentation as an important practical scientific skill must begin with students' clarification of the basic connotations of scientific argumentation, and students are rarely able to fully articulate the basic elements of scientific argumentation in the actual physics learning process. However, teachers cannot directly instil the basic elements of scientific argumentation. Although students understand it relatively quickly, they are basically at the level of superficial understanding and are not able to deeply understand and enhance students' actual scientific argumentation ability. Teachers can integrate the basic elements of scientific argumentation ability into the teaching language in the actual physics teaching process, and the discourse penetrates to trigger students' thoughts, allowing them to learn and discuss independently, putting ideas, They can integrate the basic elements of opinion, evidence and theory, reasoning and rebuttal into the teaching of physics, design physics problem situations, encourage students to express their own opinions, work independently to find evidence, refine the laws of physics, construct logical reasoning, and allow students to use the terminology of scientific argumentation to evaluate and refute the opinions of others, thus helping students to develop an awareness of scientific argumentation.

4.3 Create a classroom environment for scientific argumentation and encourage students to question and refute

Teachers should first transform the teaching position, return the classroom to the students, especially in the physics investigation experiment class, students will inevitably encounter a variety of problems, first let students put forward their own views, let them discuss with each other to find each other's views of the loopholes, search for facts and evidence to question and refute the opposing views, to support their own views, in the dialogue and discussion to form the correct views, if not to form the correct If a correct view cannot be formed, the teacher needs to play a guiding role by coming forward to comment on and correct the students' views, guiding them towards a correct scientific view, and then encouraging students to give full play to their own initiative and show their own thinking process, with students evaluating each other, questioning and refuting each other, so that students have the right to speak in the classroom, they will be more likely to engage in the classroom, and more likely to collide with the sparks of thinking, creating It is important to create a good environment for scientific argumentation in the classroom, both to promote the bursting of students' thinking skills and to create a relaxed and in-depth motivation for students to learn.

References

Han, Kwai-Koi, Hu, Weiping.(2019).Research on constructing a model of scientific argumentative competence structure . Educational Theory and Practice, 39(22):3-7.
Zhou Jianwu (2017) Scientific argumentation:logic and scientific evaluation methods. Beijing:Chemical Industry Press.
Ministry of Education. (2022).Physics curriculum standards for compulsory education (2022 edition) [S]. Beijing Normal University Press.
Osborne, J. F., Henderson, J. B., MacPherson, A., Szu, E., Wild, A., & Yao, S. Y. (2016).The development and validation of a learning progression for argumentation in science[J]. Journal of Research in Science Teaching, 53(6), 821-846.
Chen Ying.(2016). Performance of high school students' scientific argumentation ability and teaching suggestions[J]. Basic Education Curriculum, (22):64-67.
Zheng Ying,Zhang Junpeng,Zhang Yufa.(2019).Performance of high school students' scientific argumentation ability in physics--a test evaluation based on Rasch model[J]. Physics Teacher,40(01):2-6.