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Original Paper

Does STEM Education Make a difference to Students' Views of Nature of Science? A Survey in Elementary Schools

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Abstract

This study aims to examine views of Nature of Science (VNOS) among elementary students, and to determine if STEM education make a difference to their VNOS. Data for this study was gathered from two elementary schools in China. One has never implemented STEM education. The other one implements STEM education as a course once or twice a week for students at different grades. Participants' VNOS was gathered through responses to Likert scale questions from the Nature of Science "Mars Mission" questionnaire. Some students and their teachers were interviewed after questionnaire survey. It was found that students who have been received STEM education show higher score of VNOS than who have never been exposed to STEM education. In different dimensions, STEM education makes a significant difference to scientific worldview, and makes a difference to scientific inquiry as well as scientific enterprise. For students never received STEM education, no relation was found between grade and their VNOS. With regards to students regularly exposed to STEM education, grade shows a strong positive relation with their VNOS. The earlier students contact with STEM education, the better their view of the nature of science.

Keywords

STEM education, views of nature of science, elementary schools

1 Introduction

Students' Views of Nature of Science (VNOS) have long been a vital component of science literacy (Afonso & Gilbert, 2010; Science for All Americans, 1990; Tyler, 2007; Upahi et al., 2020) The development of VNOS has not only been considered a significant objective of science education, but also been emphasized in much major education reforms (Clough, 2006; McComas, 2008). STEM education, first proposed by National Science Foundation in the early 2000s (Li, 2018; Sanmartino et al., 2020), is a concept where the teaching of Science, Technology, Engineering, and Mathematics is integrated as one discipline (Bybee, 2010; Xie et al., 2015), and has been widely accepted in many countries (e.g., China (Li et al., 2018; Ma, 2021), Australia (Murphy et al., 2019; Sharma & Yarlagadda, 2018), England (Ro et al., 2021; Wong et al., 2016) and Malaysia (Alam et al., 2021; Anuar & Chankseliani). As a new educational concept, STEM education is consistently implemented based on actual phenomena and situations (Jiang & Yuan, 2021; Sari et al., n.d.) through project-based learning method (Jorgenson, 2018; Lou et al., 2017; Warin et al., 2016). As is well-known, STEM education can not only enhance students' ability to solve real problems, communicate, collaborate and create, but also develop students' interests in STEM subjects and pursuance in STEM careers. (Bybee, 2010; Guzey et al., 2016; Mathis et al., 2018; Vennix et al., 2018) In this study, we aim to contribute such evidence, that how students VNOS was related to STEM education.

1.1 STEM Education

STEM comes from an acronym for Science, Technology, Engineering and, Mathematics. In the 1980 s, science popularization education paid much attention to the integration of science curriculum. Besides, there is an urgent need to cultivate high-skilled talents in the 21st century. Researchers have explored the significance of curriculum integration in STEM education. STEM education is considered capable of promoting education equity and helping students acquire the knowledge they need to compete globally (Avendano et al., 2019; Board, 2011; English, 2017), and thus has been developed into one of the focused education reforms in various countries. Owing to the need to enhance the global core competitiveness of the next generations, some developed countries have started promoting STEM education from a national strategic perspective. For example, in 2007, the United States Federal Government issued *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System*. It was stated that the United States could only succeed in this informationalized and high-tech world if all students were equipped with abilities from STEM education at levels far beyond what was considered acceptable before. (Board, 2011) Furthermore, the United States enacted *STEM Education Act of 2015* (Yee, 2015), and this showed the national determination to promote STEM education reform. The Australian government released Chief Scientist's position paper in 2014 titled *Science, Technology, Engineering and Mathematics: Australia's Future*. The report defined the developmental value of STEM education as only the knowledge provided by STEM education, and its practical application is the final way to build a more economically competitive and stronger Australia. (Chief Scientist, 2014) In order to achieve the construction of STEM curriculum resources, the research of STEM integration project was conducted and led by Australian Curriculum, Assessment and Reporting Authority. In addition, European countries such as the UK and Germany included STEM courses in their curriculum standards.

1.2 Nature of Science

Nature of Science (NOS) has been widely defined in literature differently. William et al. (William et al.,

1998) believed that NOS is a hybrid field, combining cognitive science with various dimensions of social science, such as history, sociology, and philosophy of science. It formed a detailed and useful description of science and its functions. Lederman (Lederman, 1992) stated that NOS referred to the epistemology of science, science as how of knowing, or the values and beliefs inherent to knowledge or the event of knowledge. Akerson and coworkers (Akerson et al., 2000) explained that K-12 grade students should understand NOS with the following dimensions: (1) Scientific knowledge can be changed; (2) Science is empirically based; (3) Science is subjective; (4) Science is part of the product of human inference, imagination, and creativity; (5) Science is embedded with society and culture; (6) observations and inferences are distinguishing; (7) Scientific theories and laws are distinguishing. Good (Good & Shymansky, 2001) believed that NOS is the sum of the scientific thinking process and scientific knowledge system. American Association for the Advancement of Science (AAAS) advanced NOS as three dimensions: scientific worldview, scientific inquiry, and scientific enterprise. (Science & Washington, 1995)

1.3 Views of NOS

Views of NOS (VNOS) refer to one's understanding of the NOS. VNOS can be measured by questionnaire. Klopfer and Cooley (Cooley & Klopfer, 1961) developed a Test on Understanding Science (TOUS), which was widely used to measure students' VNOS (Aikenhead, 1972; Aikenhead, 1973; Korth, 1969). Welch (Welch, 1966) developed Science Process Inventory (SPI), suitable for high school students and adults. It includes 135 two-choice (agree-disagree) items, which cover perceptions of the role of scientists, the nature and functions of theories, underlying assumptions made by scientists, and other dimensions of the scientific process. Rubba (Rubba, 1977) used the Nature of Scientific Knowledge Scale (NSKS) to assess high school students' understanding of the nature of scientific knowledge. NSKS characterizes scientific knowledge as amoral, creative, and developmental. Lederman and coworkers (Bell et al., 2000; Lederman & Abd-El-Khalick, 2002; Lederman et al., 1998; Lederman, 1992; Lederman & O'Malley, 1990) successively developed several instruments to measure VNOS.

In recent years, more and more researchers concentrated on investigating students' VNOS. For example, a study explored secondary students' VNOS in Quantum Physics (QP) and their achievement level on an AP concept test. Results showed that all participant students presented desired views for the probed QP-related NOS dimensions. (Stadermann & Goedhart, 2020) It was suggested that making the best QP could benefit NOS teaching. A case about the development of four students' VNOS over a 13-year period was also reported. (Yacoubian, 2021) During the academic year 2006-2007, an Honors Biology course was implemented using a consensus framework of NOS, and the NOS intervention was demonstrated to be effective for students in the short term. After 12 years, the VNOS of these four students were quite different. Their VNOS was further shaped by their living environment, university learning opportunities, and career paths. From literature, it was found that boys presented more native views of the empirical NOS than girls. Moreover, third graders had more informed views of the tentative NOS than fifth and sixth graders. (Toma et al., 2019) In another article, fourth and fifth grade elementary students participated in a technology-enhanced inquiry activity occurring in formal and informal settings. Their VNOS was significantly improved after this activity. (Schellinger et al., 2019)

1.4 Research Questions

We addressed the following research questions:

RQ1: Does STEM education make a difference to elementary students' VNOS?

RQ2: To what extent does STEM education relate to elementary students' VNOS?

Most science education reform efforts suggested that it is necessary to foster the development of students' VNOS to ensure their science literacy. (McComas et al., 2015) Nowadays, STEM education has been widely implemented in many countries. The first question was motivated by the need to understand the efficiency of STEM education from the perspective of students' VNOS. The second question was to find the relationship between STEM education and students' VNOS. These results would be of great interest in knowing which aspects of educational interventions should focus on improving students' VNOS.

2 Methodology

2.1. Research Process of the Study

We conducted a mixed-method study to investigate it in in-depth details. First, the researcher collected quantitative data by distributing a questionnaire to students in two elementary schools. After that, the researcher interviewed 8 students and 4 elementary teachers. After data collection, the researcher analyzed quantitative and qualitative data to investigate the selected research topic thoroughly and to propose implications for science education

2.2 Sample of Research

Students from two elementary schools participated in this study. Both elementary schools are public schools located in the urban area of Wenzhou, China. Elementary school A has never implemented STEM education. Elementary school B implements STEM education as a course once or twice a week for different grades. Normally, the learning contents are based on what students have learnt in the textbooks during this semester. For example, students at fourth grade have learnt telescopes assembled with convex and concave lenses in the class. In the STEM course, the application of telescopes was involved, such as exploring the universe. Considering that junior grade students cannot complete the questionnaire dependently, only students from grade three to six (aged 9 to 12) were surveyed. Particularly, except for implementation of STEM education, the two elementary schools are very similar in terms of nature, admission conditions, teaching schedule, teaching mode and main curriculum settings. Before the questionnaire survey, participants were told it was anonymous and voluntary. To ensure the validity of the investigation, there are few differences between the number of respondents in School A and School B according to their gender and grade. Table 1 shows the respondents' demographic information. For the qualitative part, the researcher interviewed 8 students and 4 elementary teachers in this study. These students and elementary teachers are from different schools and different grades.

Table 1. Demographic Information of the Respondents

	Frequency	%		Frequency	%
School A	137		School B	133	
Gender			Gender		
Male	77	56.2%	Male	75	56.4%
Female	60	43.8%	Female	58	43.6%
Grade			Grade		
3	33	24.1%	3	33	24.8%
4	32	23.4%	4	26	19.5%
5	39	28.5%	5	41	30.8%
6	33	24.1%	6	33	24.8%

2.3 Survey Instrument

For the quantitative part of the current study, we used a paper questionnaire. The questionnaire firstly collected demographic information (gender and grade). Participants' VNOS was gathered through responses to Likert scale questions from the Nature of Science "Mars Mission" questionnaire(Wang 2021). For the purpose of this study, AAAS's NOS framework was used. (Science & Washington, 1995) Three dimensions were involved in this questionnaire: scientific worldview, scientific inquiry, and scientific enterprise. There are 36 questions. The positive (+) questions and negative (-) questions were randomly distributed to depict students' views on the various dimensions of NOS. A complete overview of all items in the questionnaire can be found in Table 2. Internal consistency was assessed using Cronbach's alpha coefficient (α=0.735), demonstrating the results are acceptable. (Del Castanhel et al.) The results of the questionnaire are presented in Appendix 1.For the qualitative part, semi-structured interview questions were prepared (Appendix 2).

Table 2. Dimensions of NOS, Items, Codes and Corresponding Questions in the Questionnaire

Dimension of NOS	Items	Corresponding questions
Scientific worldview (X)	Scientific knowledge can be understood. (X1)	32 (+)
	Scientific knowledge is temporary. (X2)	13 (-),36 (-)
	Scientific knowledge can be verified (X3)	3 (+),16 (+),18 (+),23 (+)
	Scientific knowledge is integrated. (X4)	1 (+),19 (+)、
	Scientists cannot be wholly objective and	7 (+),12 (-),15 (-), 19

	value-neutral. Scientific knowledge is only a scientist's worldview. (X5)	(-),26(+)
Scientific inquiry (Y)	The scientific method that can solve the research problem is a good scientific method. There is no invariable scientific method. (Y1)	4 (+),11 (-),35 (+)
	Similarities and differences in the establishment of scientific hypotheses, theories and laws, models and classification systems, and their roles in the development of science. (Y2)	2 (+),6 (-),10 (-),14 (+),20 (-),21 (+), 27 (+),28 (-),29 (+), 31 (+),33 (-),34 (-), 35 (+)
Scientific enterprise (Z)	There is an interaction among science, technology and society. (Z1)	8 (+),9 (-),17 (-),22 (+),25 (-)、30 (+)
	The scientific community influences scientific research. (Z2)	5 (-),24 (+)

2.4 Data Analysis

For every positive response, points got from 1 to 4. For instance, strongly disagree = 1, disagree = 2, agree = 3 and strongly agree = 4. Similarly, for every negative response within the scale, the scores were appointed in reverse order from 4 to 1. For instance, strongly disagree = 4, agree = 3, agree = 2 and strongly agree = 1.The data were analyzed using an online data analysis platform SPSSAU (https://spssau.com/). The qualitative data were analyzed by means of conventional content analysis.

3 Findings

3.1 Differences of Students' VNOS

Table 3 reports the descriptive results from the VNOS test, and the corresponding data are displayed in Figure 1. Having considered a maximum score of 4 (strongly agree) and a minimum of 1 (strongly disagree), both school A and school B participants present high VNOS. Participants from school B score higher on VNOS and all dimensions than those from school A. According to the independent t test results, there are significant differences in VNOS between school A and school B ($t=-2.824$, $p=0.005<0.01$). There is also significant difference in the dimension of X between school A and school B ($t=-2.615$, $p=0.009<0.001$). Besides, there is difference in the dimension of Y ($t=-2.442$, $p=0.015<0.05$) and Z ($t=-2.013$, $p=0.045<0.05$) between school A and school B. Particularly, the results of standard deviation show that VNOS and corresponding dimensions of students in school A differ more than that of students in school B. This indicates that STEM education can make a difference to students' VNOS. After receiving STEM education, students' VNOS gradually unified.

Table 3. Descriptive Results from the VNOS Test

		X	Y	Z	VNOS
School A	Mean	2.896	2.995	2.978	2.955
	Std.	0.278	0.304	0.386	0.268
School B	Mean	2.986	3.124	3.065	3.042
	Std.	0.260	0.284	0.358	0.239
t		-2.615	-2.442	-2.013	-2.824
p		0.009**	0.015*	0.045*	0.005**

$^*p<0.05$ $^{**}p<0.01$.

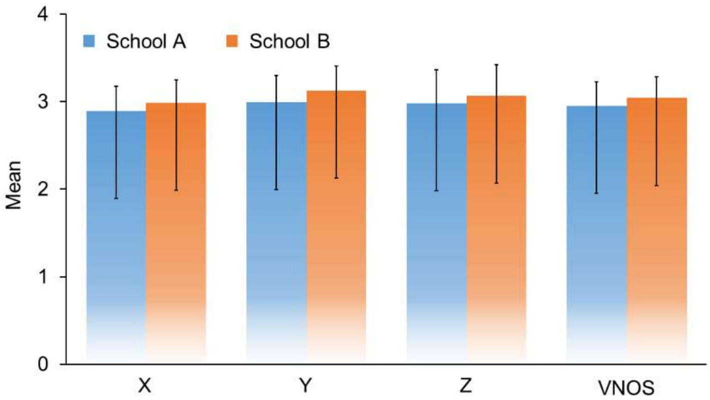

Figure 1. The Results from Students' VNOS Test in School A and School B

3.2 Differences of Students' VNOS in Various Dimensions

To visually present the difference of students' VNOS in various dimensions between school A and school B, the results are exhibited in Figure 2.

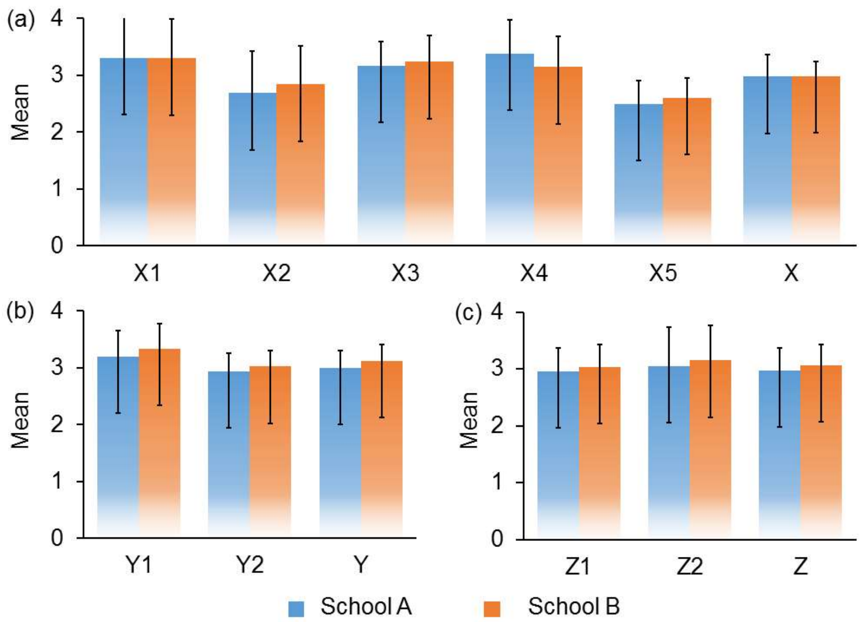

Figure 2. Results from Students' VNOS Test in the Dimensions of (a) Scientific World View; (b) Scientific Inquiry and (c) Scientific Enterprise

The descriptive results from students' VNOS test in the dimensions of scientific worldview are summarized in Table 4. Participants from school B score higher in scientific worldview dimensions than those from school A. Except for item X4, the other items of school B present higher mean scores than those of school A. Based on the independent t test results, STEM education has not significantly impacted students' VNOS in the item of X1, X1, X3, or X4. There is difference in the item of X5 (t=-2.549, p=0.011<0.05). Contentanalysis of student responses during the interview supported the result. For example, when asked "Canscientific knowledge be changed once formed?" Students in schools Aexpressed certainty. They thought scientific knowledge are infallible. Things are much better at school B.Less students thought scientific knowledge cannot be changed in school A.

Table 4. Descriptive Results from Students' VNOS Test in the Dimensions of Scientific World View

		X1	X2	X3	X4	X5	X
School A	Mean	3.307	2.69	3.175	3.383	2.501	2.978
	Std.	0.743	0.743	0.419	0.601	0.407	0.386
School B	Mean	3.301	2.846	3.241	3.147	2.603	2.986
	Std.	0.685	0.68	0.465	0.543	0.354	0.260
t		0.067	-1.799	-1.215	-0.331	-2.549	-2.615
p		0.947	0.073	0.226	0.741	0.011*	0.009**

* p<0.05 ** p<0.01.

Table 5 presents descriptive results from students' VNOS test in the dimensions of scientific inquiry. Overall, students from school B have better views of scientific inquiry than students from school A. There are differences between students' VNOS test in the dimensions of scientific inquiry (t=-2.442, *p*=0.015). As for the item Y1 and Y2, differences also exist. This indicates that STEM education impacts students' VNOS in the dimensions of scientific inquiry. When asked "Mars probes can land on Mars. Can they successfully land on other planets?", students from different school held different views. Students from school A said since Mars probes can land on Mars, it should be able to land on other planets. Students from school B disagreed. They thought Mars probes could provide guidance on exploring other planets, but it doesn't mean Mars probes can land on other planets. They said everything on other planets was still unknown, and the environment in different planets, such as temperature, humidity, light, were diverse. Evidently, Students from school B have deeper understanding than who from school A on a concrete analysis of concrete in scientific research.

Table 5. Descriptive Results from Students' VNOS Rest in the Dimensions of Scientific Inquiry

		Y1	Y2	Y
School A	Mean	3.200	2.938	2.995
	Std.	0.458	0.313	0.304
School B	Mean	3.331	3.024	3.124
	Std.	0.447	0.283	0.284
t		-2.384	-2.352	-2.442
p		0.018*	0.019*	0.015*

* $p<0.05$ ** $p<0.01$.

The descriptive results from students' VNOS test in the dimensions of scientific enterprise are displayed in Table 6. Students from school B score higher on the VNOS test in scientific enterprise dimensions than those from school A. There are differences between students' VNOS test in the dimensions of scientific inquiry (t=-2.013, *p*=0.045). STEM education can make a difference in students' views of scientific enterprise. However, there are no differences in item Z1 and Z2. Science, technology, and society are independent and interactive, and the interaction among them will affect the development of each other. Typically, elementary students are exposed to the environment of schools but have an insufficient understanding of society. Therefore, the relationship between science and society is less understood. For the question "If you have a helpful scientist friend, will you consult him for advice on any problems (including study, daily life, social experience, etc.)?", the answer varied. Some students said they will. Because this scientist is helpful, and he can help them analyze the problems from a scientific point of view. It reflects that these students have too much trust in scientists to and feel that scientists' decisions are always scientific and can be trusted. Meanwhile, some students said they might ask this scientist for advice, but not everything. They think some questions are too simple, that it is not necessary to be ask. Another student said scientists are not good at everything, and that they may not know as much about some issues. In summary, there is still some blindness in students' understanding of scientists. In this case, teachers said, on the one hand, some students have blind faith in the authority. On the other hand, students' definition of "scientist" is not very clear. The stereotyped image of scientists are omnipotent.

Table 6. Descriptive Results from Students' VNOS Test in the Dimensions of Scientific Enterprise

		Z1	Z2	Z
School A	Mean	2.961	3.051	2.978
	Std.	0.402	0.679	0.386
School B	Mean	3.038	3.147	3.065
	Std.	0.386	0.615	0.358
t		-1.722	-1.211	-2.013
p		0.086	0.227	0.045*

* $p<0.05$ ** $p<0.01$.

3.3 Differences of VNOS at Various Grades

To better understand the influence of STEM education on elementary students' VNOS, the test results at different grades are presented. Pearson correlation coefficient was employed to determine the relations between grade and VNOS. (Hauke & Kossowski, 2011; Schneider et al., 2020) Regarding students from school A, the grade has no relation with students' VONS. This demonstrates that students' VONS does not show a difference with the grade increased without receiving STEM education. Students' VONS in the dimension of X is positively influenced by grade. With one exception,as the grade increases, the mean score of students' views of scientific worldview increases. Concerning students from school B, all the correlations presented are statistically significant. On the whole, grade shows a strong positive relation with students' VNOS (r = 0.347, p=0< 0.01). Grade also positively relates to all the dimensions (X, Y, and Z) of students' VNOS. With the grade increase, students' VNOS in different dimensions show an overall upward trend. The higher the grade, the more STEM experiences are accumulated for students in school A. Hence their VNOS increases with grade.

Table 7. Descriptive Results from the Students' VNOS Test at Different Grades

			X		Y		Z		VNOS	
			Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
School A	Grade	3	2.769	0.296	2.943	0.315	2.896	0.381	2.869	0.274
		4	2.911	0.256	3.027	0.296	3.072	0.398	2.997	0.261

		5	2.959	0.281	3.038	0.31	3.004	0.415	3.001	0.284
		6	2.932	0.248	2.964	0.295	2.939	0.332	2.946	0.236
	r		0.217*		0.029		0.019		0.101	
	p		0.011		0.738		0.824		0.241	
School B	Grade	3	2.890	0.238	3.037	0.265	2.924	0.283	2.947	0.194
		4	2.915	0.271	3.047	0.330	3.005	0.491	2.965	0.283
		5	2.988	0.217	3.141	0.266	3.168	0.323	3.072	0.212
		6	3.137	0.263	3.249	0.244	3.125	0.301	3.162	0.223
	r		0.343**		0.283**		0.243**		0.347**	
	p		0		0.001		0.005		0	

* $p<0.05$ ** $p<0.01$.

The mean scores of students' VNOS and corresponding dimensions are plotted in Figure 3. It was found that students' VNOS does not present clear trends with the increasing grades in school A. On the contrary, there is a growing tendency of students' VNOS in school B as the grade increases. This also shows that STEM education positively makes a difference to elementary students' VNOS.

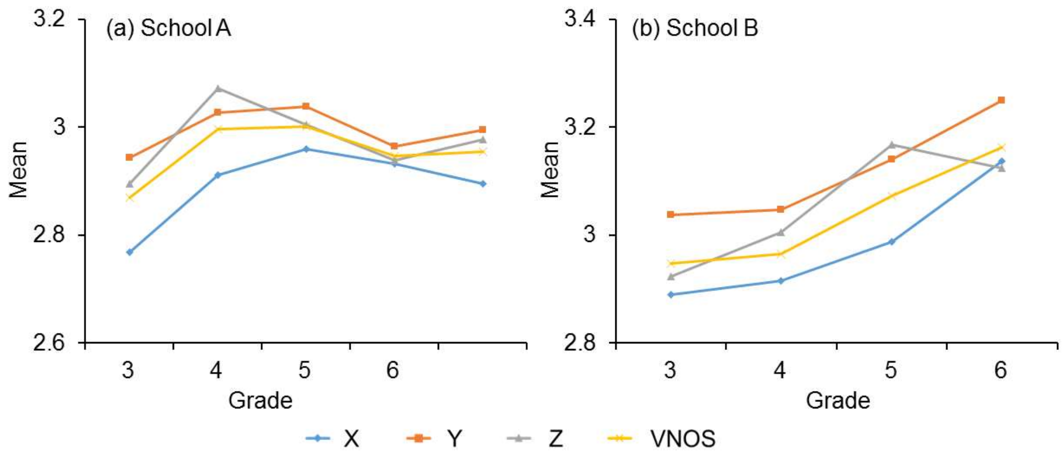

Figure 3. Results from Students' VNOS Test at Different Grades

4 Discussion

4.1 Does STEM Education Make a Difference to Elementary Students' VNOS?

In relation to the first research question, the results show that STEM education does make a significant difference to student's VNOS. Students who received STEM education show a higher score of VNOS than those who have never been exposed to STEM education. Students from school B score higher than those from school A in all dimensions.

4.2 To What Extent Does STEM Education Relate to Elementary Students' VNOS?

An independent *t* test was performed to determine whether there are significant differences in students' VNOS. Results indicate that students from school A and B present a significant difference in VNOS. In different dimensions, STEM education makes a significant difference to scientific worldview, and makes a difference to scientific inquiry as well as scientific enterprise. A Pearson correlation was performed to establish whether students' VNOS and their grades were related. For students from the school that never implemented STEM education, no relation ($r=0.101$, $p=0.241$) was found between grade and their VNOS. With regards to students from the school that implements STEM education as a course once or twice a week, grade shows a strong positive relation with students' VNOS ($r = 0.347$, $p=0 < 0.01$) as well as all three dimensions. At higher grade levels, students' VNOS increases. This result suggests that, in our sample, STEM education does impact student VNOS. The more STEM-educated elementary students are, the more they report a high score on VNOS. According to previous research, STEM education can promote scientific literacy(Aguilera & Ortiz-Revilla, 2021; Hoeg & Bencze, 2017; Ortiz-Revilla et al., 2022). Early research also demonstrates that curriculum and teaching practices influence NOS views (Lederman, 1986; Zeidler & Lederman, 1989). Results from this study are in accord with previous results obtained in these literatures.

4.3 Limitations

There are some limitations that may be found in this study. The sample was relatively small. Only students from two schools were surveyed. The sampling size is not enough, and the findings and results of the current study might not be able to be generalized due to this small number of participants.

5 Implications for Science Education

Firstly, it is essential to implement STEM education in elementary schools. Because STEM education has a positive effect on students VNOS. A meta-analysis revealed that STEM education paves the way for academic achievement, especially in science (Kazu, 2021). Another meta-analysis also proved that STEM education was more effective in increasing students' achievement in science courses compared with teacher-centered teaching methods (Akici et al., 2021).

Secondly, elementary students are supposed to be exposed to STEM education sooner rather than later. The earlier students contact STEM education, the better their VNOS. STEM education was firstly proposed to improve the quality of undergraduate education (Li, 2018). Afterward, it was introduced into elementary and secondary science classrooms. More recently, studies revealed that STEM education likewise contributes to the development of science literacy of preschool children (Ceylan & Malcok, 2020; Wan et al., 2021; Yucelyigit & Toker, 2021).

Thirdly, more content related to society should be included in STEM courses. It was found elementary students do not really understand the relationship between science, technology, and society. In the 1980s, Science, Technology and Society (STS) education was introduced in science education by encouraging students to utilize their daily experiences to understand essential features of their social environment. It has been demonstrated that STS education can promote students' science literacy (Mulyanti et al., 2021) and use of moral judgments on socio-scientific issues (Evren Yapicioğlu & Kaptan, 2017), enhance science motivation (Cigdemoglu, 2020), and develop soft skills such as communication, interpersonal skills, and professionalism (Roswita et al., 2021).

Finally, the image of scientists should be involved in STEM courses. It has been proved that, in the cognition of kindergarten students and first-year students in elementary schools, images of scientists are seldom seen. These images start to appear in the cognition of second-year students in elementary schools. By the fifth grade, students have mature understanding of the images of scientists. (Chambers, 1983) Research has also shown that fifth grade students created images of scientists with more stereotypical elements compared to drawings created by students in kindergarten and grade 3. (Özel, 2012) It would be important to employ a variety of activities related to images of scientists in STEM course.

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Appendix 1

The Results of Questionnaire (Translated by the Author)

	Question		Frequency(%)	
			School A	School B
1	What scientists know about Mars has been slowly accumulated through observation and exploration.	SA	104(75.9%)	106(79.7%)
		A	32(23.4%)	27(20.3%)

		D	1(0.7%)	0(0%)
		SD	0(0%)	0(0%)
2	The understanding of Mars by scientist today may not be the understanding of Mars by scientist used to be.	SA	64(46.7%)	72(54.1%)
		A	65(47.4%)	54(40.6%)
		D	7(5.1%)	6(4.5%)
		SD	1(0.7%)	1(0.8%)
3	To prove that there is water on Mars, you need to find evidence of water.	SA	81(59.1%)	85(63.9%)
		A	43(31.4%)	39(29.3%)
		D	10(7.3%)	8(6%)
		SD	3(2.2%)	1(0.8%)
4	The Invention of the Mars Reconnaissance Orbiter is a good way for scientists to explore Mars, and there should be other ways to explore Mars.	SA	74(54%)	79(59.4%)
		A	58(42.3%)	48(36.1%)
		D	4(2.9%)	5(3.8%)
		SD	1(0.7%)	1(0.8%)
5	If there are new discoveries on Mars, scientists should keep them to themselves, not to the world.	SD	42(30.7%)	58(43.6%)
		D	53(38.7%)	42(31.6%)
		A	27(19.7%)	24(18%)
		SA	15(10.9%)	9(6.8%)
6	Even if hematite and other water-related evidence were found, there is no way to conclude that water might have existed on the surface of Mars in the past.	SD	12(8.8%)	19(14.3%)
		D	41(29.9%)	36(27.1%)
		A	44(32.1%)	46(34.6%)
		SA	40(29.2%)	32(24.1%)
7	Even for the same sample, after analysis of the data, different scientists may give different interpretations.	SA	70(51.1%)	78(58.6%)
		A	59(43.1%)	52(39.1%)
		D	7(5.1%)	2(1.5%)
		SD	1(0.7%)	1(0.8%)
8	When conducting research on Mars, scientists should consider not destroying the Martian environment.	SA	101(73.7%)	98(73.7%)
		A	25(18.2%)	28(21.1%)
		D	5 (3.6%)	3(2.3%)
		SD	6 (4.4%)	4(3%)
9	The knowledge gained by exploring Mars is only useful to scientists, not relevant to the lives of the other people.	SD	55(40.1%)	64(48.1%)
		D	47(34.3%)	49(36.8%)
		A	17(12.4%)	10(7.5%)
		SA	18(13.1%)	10(7.5%)
10	Scientists do not need imagination when work on	SD	55(40.1%)	69(51.9%)

	Mars.	D	45 (32.8%)	48(36.1%)
		A	20 (14.6%)	9(6.8%)
		SA	17 (12.4%)	7(5.3%)
11	There is no scientific way to explore Mars other than by launching spacecraft and using telescopes.	SD	59(43.1%)	66(49.6%)
		D	56(40.9%)	57(42.9%)
		A	16(11.7%)	5(3.8%)
		SA	6(4.4%)	5(3.8%)
12	If a new discovery was found, it must be admitted by majority of scientists.	SD	11(8%)	9(6.8%)
		D	16(11.7%)	26(19.5%)
		A	60(43.8%)	52(39.1%)
		SA	50(36.5%)	46(34.6%)
13	Mars is currently considered the most likely place to have life, and that view is unlikely to change in the future.	SD	30(21.9%)	30(22.6%)
		D	65(47.4%)	83(62.4%)
		A	26(19%)	13(9.8%)
		SA	16(11.7%)	7(5.3%)
14	A deeper understanding of Mars must be based on accumulated experience through constant observation.	SA	93(67.9%)	96(72.2%)
		A	36(26.3%)	30(22.6%)
		D	4(2.9%)	5(3.8%)
		SD	4(2.9%)	2(1.5%)
15	We should have complete confidence in the results of authoritative scientists' research on Mars.	SD	25(18.2%)	21(15.8%)
		D	64(46.7%)	84(63.2%)
		A	28(20.4%)	14(10.5%)
		SA	20(14.6%)	14(10.5%)
16	Knowledge of Mars need be supported by many scientists.	SA	75(54.7%)	68(51.1%)
		A	49(35.8%)	56(42.1%)
		D	9(6.6%)	5(3.8%)
		SD	4(2.9%)	4(3%)
17	A scientist expert in Mars can be trusted to engage with other social issues (education, the economy, unemployment) as much as he has with Mars research.	SD	18(13.1%)	14(10.5%)
		D	28(20.4%)	46(34.6%)
		A	61(44.5%)	51(38.3%)
		SA	30(21.9%)	22(16.5%)
18	We can know about Mars without the support by scientists' research.	SD	59(43.1%)	53(39.8%)
		D	41(29.9%)	53(39.8%)
		A	17(12.4%)	8(6%)
		SA	20(14.6%)	19(14.3%)

19	Different scientists have similar views on Mars research, regardless of their own past experiences.	SD D A SA	27(19.7%) 44(32.1%) 36(26.3%) 30(21.9%)	22(16.5%) 50(37.6%) 33(24.8%) 28(21.1%)
20	Studies of Mars can be done quickly and do not require long observation and exploration.	SD D A SA	81(59.1%) 39(28.5%) 6(4.4%) 11(8%)	78(58.6%) 42(31.6%) 3(2.3%) 10(7.5%)
21	As technology advances, scientists can learn more about Mars.	SA A D SD	97(70.8%) 38(27.7%) 1(0.7%) 1(0.7%)	92(69.2%) 35(26.3%) 4(3%) 2(1.5%)
22	Scientists should also participate in social issues (education, economics, career), but the proposed solutions may not be reliable.	SA A D SD	32(23.4%) 67(48.9%) 33(24.1%) 5(3.6%)	33(24.8%) 72(54.1%) 25(18.8%) 3(2.3%)
23	Scientists should take the results of other scientists' research on Mars with a grain of salt.	SA A D SD	41(29.9%) 41(29.9%) 40(29.2%) 15(10.9%)	40(30.1%) 50(37.6%) 37(27.8%) 6(4.5%)
24	What scientists find on Mars should be made public in due course.	SA A D SD	61(44.5%) 49(35.8%) 22(16.1%) 5(3.6%)	53(39.8%) 53(39.8%) 24(18%) 3(2.3%)
25	Sometimes in order to do research, scientists don't have to worry about damaging the Martian environment.	SD D A SA	78(56.9%) 31(22.6%) 11(8%) 17(12.4%)	83(62.4%) 27(20.3%) 11(8.3%) 12(9%)
26	If a scientist proposes a new research result, it need not be agreed upon by the same scientists who study Mars.	SA A D SD	14(10.2%) 22(16.1%) 46(33.6%) 55(40.1%)	25(18.8%) 15(11.3%) 46(34.6%) 47(35.3%)
27	Scientists working on Mars sometimes need to use their imagination to explain their findings.	SA A D	36(26.3%) 65(47.4%) 25(18.2%)	47(35.3%) 65(48.9%) 17(12.8%)

		SD	11(8%)	4(3%)
28	Advances in science and technology have nothing to do with what scientists know about Mars.	SD	61(44.5%)	78(58.6%)
		D	49(35.8%)	36(27.1%)
		A	14(10.2%)	7(5.3%)
		SA	13(9.5%)	12(9%)
29	The Martians, as far as science has gathered evidence, are confirmed to exist.	SA	22(16.1%)	10(7.5%)
		A	36(26.3%)	34(25.6%)
		D	51(37.2%)	58(43.6%)
		SD	28(20.4%)	31(23.3%)
30	What we know about space will affect our lives.	SA	34(24.8%)	31(23.3%)
		A	39(28.5%)	39(29.3%)
		D	49(35.8%)	35(26.3%)
		SD	15(10.9%)	28(21.1%)
31	The discovery of hematite on the surface of Mars leads us to conclude that there may have been water on the surface of Mars in the past.	SA	47(34.3%)	40(30.1%)
		A	71(51.8%)	73(54.9%)
		D	12(8.8%)	14(10.5%)
		SD	7(5.1%)	6(4.5%)
32	When we look at the dark red glow of Mars, I believe it must be caused by something.	SA	61(44.5%)	56(42.1%)
		A	61(44.5%)	62(46.6%)
		D	11(8%)	14(10.5%)
		SD	4(2.9%)	1(0.8%)
33	Scientists are learning more about Mars than ever before by looking at it through telescopes.	SD	22(16.1%)	19(14.3%)
		D	47(34.3%)	57(42.9%)
		A	39(28.5%)	29(21.8%)
		SA	29(21.2%)	28(21.1%)
34	Mars Exploration Satellite can successfully land on the surface of Mars. I believe it will also successfully land on other planets.	SD	10(7.3%)	15(11.3%)
		D	36(26.3%)	32(24.1%)
		A	36(26.3%)	37(27.8%)
		SA	55(40.1%)	49(36.8%)
35	The hematite minerals found on Mars may have been there before, not because of some Martian change.	SA	37(27%)	45(33.8%)
		A	57(41.6%)	59(44.4%)
		D	32(23.4%)	22(16.5%)
		SD	11(8%)	7(5.3%)
36	Science cannot solve all the difficulties that humans face when exploring Mars.	SD	31(22.6%)	27(20.3%)
		D	40(29.2%)	57(42.9%)

	A	44(32.1%)	27(20.3%)
	SA	22(16.1%)	22(16.5%)

Appendix 2

Interview Outline (Translated by the Author)

For students.

Q1: Can scientific knowledge be changed once formed? Why?

Q2: Does all scientists agree on what we know about science? What do you think?

Q3: Can we trust the research conclusions of famous scientists? Tell your reasons.

Q4: When a scientist does research, does his past understanding affect his research process or conclusion?

Q5: Mars probes can land on Mars. Can they successfully land on other planets?

Q6: If you have a helpful scientist friend, will you consult him for advice on any problems (including study, daily life, social experience, etc.)?

Q7: Is science responsible for today's good life? What do you think?

For teachers.

Q1: How do you like students generally affirm the authority of scientists?

Q2: We found that the grade has no relation with students' VONS in school A. As the grade increases, the mean score of students' views of scientific worldview increases in school B. What do you think is the possible reason?

Q3: What do you think are the advantages and disadvantages of current STEM courses?