



## DEVELOPING A TOOL TO ASSESS STUDENTS' VIEWS OF NATURE OF SCIENCE IN VIETNAM

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### ABSTRACT

Nature of Science (NOS) is a common topic in science education nowadays. However, to classify the nature of science is not totally consensus through documents. The assessment of views of nature of science, therefore, was facing multi issues. Especially, in assessing views of NOS in a new context other than from where a validated tool was developed. Researchers and educators should notice certain issues relating to NOS. This paper will provide and discuss how to develop a more appropriate NOS tool to best use for Vietnamese Physics student teachers based on some previously validated tools and the empirical data from the research on the context. Instead of using a provided tool robotically, the paper calls for a more critical employment of the tool based on the consideration of social and cultural context. This is not only important in the case of Vietnam but also in any new circumstance.

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### INTRODUCTION

Assessing a human's mind is never an easy mission. Research indicated difficulties in examining the progress of NOS understanding mainly because the aspects of NOS cannot be exactly categorized. Furthermore, the instruments for assessing students' and teachers' understandings of NOS have not yet generally accepted and approved widely (Lederman et al., 2014; Lederman & Lederman, 2012, 2014a, 2015; Sumranwanich & Yuenyong, 2014; Attapan & Yuenyong, 2019). There are various instruments to assess NOS understanding (e.g., a summarized Nature of Science Instruments can be looked in Lederman & Lederman (2014b). Yet, as criticised by Lederman

in this review (2014) "most of the instruments address only certain aspects of NOS and often inappropriately confuse the issue by addressing areas other than NOS, including science process skills and attitudes toward science." In more detail, generally, the important criticisms of an assessment instrument may include the following issues. Complex or ambiguous language, questions that have no clear "right" answer (or have more than 1 "right" answer). The imposition of expert's views no consensus on what "the nature of science" includes. It has to cover more things than just NOS. Researchers misinterpret the participant's responses. There is different epistemology in different cultures (of scientific knowledge and enquiry, views on science, attitudes to science, etc.). Open-ended items are unsuitable for testing large groups. Open-ended items may receive no response. It's time-consuming. There

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is a problem of language translation (when using a foreign tool). It does not regard the social and cultural traditions of the participants.

From the above criticisms, there is no best instrument to be used in a specific context. Several “try-outs” were conducted to assess Vietnamese views of NOS using a Western tool (i.e. VNOS-C of Lederman et al., 2013) revealed noticeable challenges that sometimes cannot be solved altogether. We discussed problems of assessing NOS’s understanding in Vietnam with the suggestions for researchers in somewhere else (Thao-Do & Yuenyong, 2017). Generally, these dilemmas include the consideration on the type, time, content, epistemology and terminology, and several social and cultural traditions (including passive learning style; participants’ scare of making mistake; and the balance of “give” and “gain”) under critics in the impact of social and cultural context.

It should be appreciated that a validated instrument developed by experts is always a good choice for other researchers, especially the “newcomers”. It is simply because developing a measure is hard work, and developing a good measure is much harder to ensure the validity, reliability, and effectiveness of that measure. The instruments’ validity is always a noticeable problem (Gall et al., 1996). To assure validity, reliability, and increase the effectiveness of instrument, researchers usually consider the following matters. These included well-tested factorial structure, reliability and validity, the availability of normative data, user-friendliness and administrative ease, the online availability, financial cost, short length vs. long length, availability of supportive materials and technology to enter, analyse and interpret results, and applicable to a wide range of participants.

Undoubtedly, it is not easy to manage all of these things. For that reason, the newcomers in a research field mostly employ a validated tool in their research with minor modifies. It is especially true for young researchers from developing countries such as Thailand or Vietnam. From the author’s communications among the science education community in Thailand, in assessing the nature of science understanding, most of the young researchers will choose different forms of Nature of Science (VNOS) view of Lederman and his colleagues because this is an open-ended tool which can explore alternative ideas in a new context thanks to two main reasons as noted by Lederman & Lederman (2014): first, allow respondents express their own views toward the topic; second, avoid the imposition of researcher’s

views. Unfortunately, a well-validated instrument may not work well in another context different from where the instrument is validated. Therefore, pilot test is always necessary to be applied before using it on a large scale.

The barrier of language is always a problem in using a validated instrument in another language other than the native one. Differing idioms and colloquialisms can cause a translated instrument to have less reliability in the instrument itself and in interpreting results (Campanile et al., 2015; Holliday & Lederman, 2014; Lederman et al., 2012; Lederman et al., 2014; McComas & Kampaourakis, 2015; Sumranwanich et al., 2016; Warwasith et al., 2019). In this case, most researchers think of the back-translation method as a way to ensure the correct language expression. Unfortunately, language is not the only difficulty. As presented previously, there are many more dilemmas to consider.

Based on Lederman & Lederman (2014) the use of standardized instruments to examine students’ NOS views has two major criticisms related to these instruments’ validity and a third criticism relates to the use of standardized instruments. First, those instruments were developed based on an erroneous assumption that respondents perceive and interpret an instrument’s items or test statements in the same way as researchers do (Aikenhead & Ryan 1992; Schwartz et al., 2012; Lederman et al., 2014). Also, the respondents are supposed to have reasons that coincide with their choice (agree or disagree). Second, Lederman et al. (2013) argued that standardized instruments probably represented their developers’ NOS aspects and biases. Being of the forced-choice category, the instruments ended up imposing the developers’ aspects of respondents. Responses to instrument items were usually designed with certain philosophical positions in thoughts. Thus, the views could support the respondents to provide their existing conceptions of NOS. Third, the standardized instruments are appropriate for large-scale assessments and generating summative measures of the capability of learners’ NOS views. It will present student views as numerical values to represent satisfactory or unsatisfactory. However, instrument developers did not explain what numerical value on such instruments established an adequate view of NOS (Aiemsang-ang & Yuenyong, 2018; Bartos & Lederman, 2014; Lederman & Lederman 2014; Pagsangkanae et al., 2019; Srisawat et al., 2018). As such, the use of standardized instruments limits the viability of any improvements in understanding NOS achieved by students. In as-

sessing human thinking in a new context, the use of a standardized instrument will shape the researchers as a positivist thinker where the responses are all planned, expected, and oriented instead of appreciating alternative ideas other than the expert views.

Somewhat overcome some limitations of the standardized instrument is the two-tier questionnaire. A two-tier questionnaire such as the Views on Science–Technology– Society (VOSTS) questionnaire can reduce the two major limitations invalidity. The VOSTS is an inventory of multiple-choice items. Each item contains a statement with several related reasoned positions. These positions were derived from Canadian high school students' responses to VOSTS items and follow-up interview questions under a student-centered approach. By substituting student response patterns to positions derived from a theoretical viewpoint, Aikenhead & Ryan (1992) were able to construct an empirically based instrument with a high degree of validity. However, as criticized by Lederman et al. (2013), when used outside the Canadian context, the VOSTS should be revised to appropriate to those contexts. Because of the various choices of the VOSTS probably limits the respondents' positions. For non- Canadian and non-Western students, the various VOSTS positions should be revised to represent the context of the researchers (Abd-El-Khalick & Bou-Jaoude 1997). This indicated the necessity of the choice so that the participants can freely express their ideas.

An open-ended questionnaire can avoid the problems inherent in the use of standardized forced-choice instruments, and also make the instrument more “international” where any idea of the participant was counted. For that reason, a slightly modified VNOS-C of Lederman et al. (Lederman et al., 2002) was used as the data collecting tool in our series of research at first. This version of VNOS-C was made by Goff et al. (2012) in which the question about “species” was replaced by the question of “element”. This version of VNOS-C was pilot used as a NOS pre-test tool in a NOS workshop organized in Vietnam in March 2013 and resulted in many un-expected problems, yet with important experiences which were mentioned in detail in another paper from the authors (Thao-Do & Yuenyong, 2017). The idea of developing a more suitable tool to assess NOS in Vietnam starting from the experiences gained from these problems with the high consideration of Vietnamese traditions, culture, and social norms.

## METHODS

This study regarded the interpretive research paradigm that considered descriptive context-based to understand participants' ideas, beliefs, valued and associated social actions. The interpretation will collect as much information and from as many perspectives as possible through various ways and multiple data sources (Taylor et al., 2012). From that, the tool for assessing Vietnamese views of NOS was developed, tested, and revised from cultural situatedness. In another word, cultural situatedness could influence students' understanding of NOS because students need to shape ideas about NOS through cultural, social, political and economic imperatives.

Based on the previously validated instrument, the instrument was also developed based on the empirical data from many channels. Part of the results from our constructivist learning environment study, on the scientific uncertainty scale (Thao-Do et al., 2016 ). Results from the pilot test of VNOS-C, where the open-ended questions resulted in several alternative ideas that indicated a deep impact of Vietnamese philosophy other than the expert views. Vietnamese participants' views from a NOS training workshop to introduce the concepts of NOS for Vietnamese educators and pre-service teachers with notes on Vietnamese views of NOS. A report on the workshop outcomes was published elsewhere (Yuenyong & Thao-Do 2015). In this workshop, a constructivist lens was employed in designing activities and discussion questions to let the participants reflect and construct the concepts of NOS by themselves as well as reveal their thinking instead of shaping their views. Guide and reflective questions were made to help the participants focus on the nature of science and scientific activities. A thoughtful critical analysing on Vietnamese philosophy, history, cultural and social traditions were made to help the researchers figure out the problems and the reasons behind them, as well as to propose solutions for those problems.

Then, a revised NOS assessment questionnaire, being called the Vietnamese View of Nature of Science Questionnaire (VN-VNOSQ) in this study, was developed. This questionnaire was mainly based on VNOS-C of Lederman & Lederman (2014) and some ideas from the “myths of science” of McComas & Nouri (2016) together with the empirical data from our previous studies. The VN-VNOSQ contains both multiple-choice questions with space for supporting ideas

and open-ended questions. The main principle is that there are no “closed” questions. The participants are encouraged to freely add their own view and supporting ideas in every item. Most of the validated questions in VNOS-C were kept except the revisions to make them a Physics-specialized instrument that combines multiple choices – short answer – and open-ended parts. The provided choices significantly reduce the time for completing the form because the participants do not have to write up their response as in the original VNOS anymore. Whereas the open parts give the participants the possibility to express any of their own ideas which may differ from the provided choices to the questionnaire.

## RESULTS AND DISCUSSION

The results clarified the pilot test for the revised version of a tool for examining students' understanding of NOS called VN-VNOSQ.

The questionnaire was first developed by the authors, then was checked by 8 Physics teacher educators and pilot tested in a focus group of 42 student teachers of Physics Teacher Education Department, School of Education, Can Tho University. Based on the responses and suggestions from the participants, several revisions were made. The provided choices in the final version (table 1) were designed not only based on expert views but also based on the participants' views from the empirical data of previous research and the pilot testing group. The questionnaire contains 11 main questions, each may include from several to the maximum of 14 statements. The important keywords in the statements are highlighted using a different font (bold and/or italic) to help the readers focus on the main topic of the statements. Some items in the Vietnamese View of NOS Questionnaire presented under a Likert scale, with the five scores  $-2$ ,  $-1$ ,  $0$ ,  $1$ ,  $2$  with  $0$  is “unsure”. The reason to offer an “unsure” option is that, as indicated by Aikenhead & Ryan (1992), students may interpret the statement in a different manner from a researcher's intention. Particularly, when they offered the chance to respond “I do not understand,” more than a quarter of respondents did so. And, it showed that when students responded “agree” or “disagree” to the item, many of those students just did not understand what the statement represents. Another issue, the Likert scales probably is subject to misrepresentation from some causes. Respondents may avoid using extreme response categories (central tendency bias); agree with statements as presented (acquiescence bias), or try to portray themselves

or their organization in a more favourable light (social desirability bias). Balancing a number of positive and negative statement multiple choices could prevent the problem of consent bias. It is obvious that simply analyse the data from the Likert scale is bias. Therefore, in VN-VNOSQ, the open part for supporting ideas or explanations was offered for every statement as a way to validate the data. The adapted bipolar Likert scale with 5 options: strongly disagree – disagree – unsure – agree – strongly agree in which the score for the scales are from minus 2 ( $-2$ ) to 2 instead of the normal 1 to 5 scales was based on these considerations: 1) the minus sign will visually and immediately indicate the disagreement, especially with science students who get used to with mathematics; 2) the differences between the two-scale 1 and 2 (or  $-1$  and  $-2$ ) will not be considered different in views; 3) in the case that the supporting ideas indicate different views from the Likert score, the supporting ideas will be the priority to indicate participant views.

The average time for Vietnamese participants to complete the form in the pilot test is around 20 minutes. With this long, we decided it as a take-home and paid survey because there is no such long spare time in the Vietnamese classroom for the survey where the time to deliver all the content required by the Ministry of Education and Training is extremely limited. The participants' ideas from the pilot test were used to revise the questionnaire to form the final VN-VNOSQ as indicated in appendices Table 1.

For each NOS aspect, the questionnaire contains several items for an inner validation to make sure that the tool can assess NOS instead of terminology and epistemology and/or avoid missing some views from the participants' perspectives. Some of the questions or statements in the instruments are not independent but closely link together since the supporting idea for one item could reveal the respondent's view in other items too. There are, in some cases, two statements with almost opposite ideas were used in parallel under the consideration that the Vietnamese view toward that problem perhaps is different from the constructivist Western NOS. For example, it is expected that some Vietnamese participants will think of scientific knowledge as being both created by human and remained outside for people to discover (Q1) due to the data from the NOS workshop for Vietnamese educators.

Data about students' understanding of NOS through VN-VNOSQ should be analysed within the lens of the interpretive paradigm to reveal a rich picture of NOS in Vietnam with the



aid of some statistics numbers. Responses from the questionnaire were coded as “More Informed” (scored 1) if they reveal to the common consensus views of NOS that summarized by McComas (2015) and Lederman & Lederman (2014) and as “More Naïve” (scored -1) if they expose the “myths of science” as indicated by McComas & Nouri (2016) or the naïve views that specified by Lederman et al. (2013). Since the supporting ideas for the levels strongly agree and agree (or strongly disagree – disagree) are quite similar, therefore, instead of consisting the result into five groups based on the Likert scale, the results were divided into these three groups with only be written by simplified scale now reduce to -1, 0, to 1. The results present the overview perspective of the respondent on an element of NOS, regarding both of their checked answers and their provided ideas.

The response will be grouped as “Unsure” and scored 0 in these cases: the response is not clear enough to put into two previous groups; the respondent check “unsure” for his answer; and the response presents both naïve and informed view with no superior idea. The reason why we did not group these cases into two different groups as “unsure” and “mix view” because it is impossible to define that a respondent chooses “unsure” (or even “don’t know” if this choice is offered) because he simply knows nothing about the statement or because he has a mixed view so that he cannot decide. In fact, in Vietnamese classrooms which the first author experience herself, even when a student answer “teacher, I don’t know” it does not mean that he really “don’t know” but most likely he is afraid of making a mistake. No matter what the teacher encourages students to express their own ideas, the problem remains in most classrooms. This is, actually, a cultural characteristic of Vietnamese students that inherits from the old, traditional teacher-centered educational system.

The analysis was performed under three processes: 1) Code the response by the checked answers to have result 1 (R1); 2) Interpret the supporting ideas to confirm or modify R1 to have result 2 (R2); and 3) Cross-check R2 by two main ways: comparison between the validate-questions in the same subject and/or using supporting ideas for other questions but share the view on the subject. R2 then were confirmed or modified the last time to have the last result (R3) for each particular idea or statement. R3 was coded by three levels: -1 (More Naïve), 0 (Unsure), and 1 (More Informed).

For the final result in a NOS aspect, which contains several particular ideas, the average score of the final results (R3s) of the ideas for that aspect was counted then was mathematically rounded to three values -1 (More Naïve), 0 (Unsure), and 1 (More Informed) to be the final result.

By triangulating the data under the analysis using these processes, it is expected that the final results present the most comprehensive and precise picture of Vietnamese NOS in which the authors’ bias or misinterpretation is at least.

Participants for the main survey are 278 third and last year student teachers of the Physics Teacher Education program. In the 278 analysed forms, no missing choice in the multiple-choice items or Likert items. This is considered a big success when every participant’s general image of science was revealed at least. However, not all participants express their ideas in the open parts. Particularly, there was an average of 40.87% of the participants provide their supporting ideas or alternative ideas for each item yet in comparison to the open-ended VNOS-C questionnaire where there are many items that could not be analyzed based on the missing answer or too short answers, it is a lot improved. The combination of multiple choices, short-answer, and open-ended questions are considered vital and necessary to use in Vietnam, especially when the Vietnamese view of NOS are not assessed anywhere else before. Almost all of the responses successfully meet the scope of the study. The given short answers minimize the vague ideas in the response and the checked responses to help the data interpretation quite easily. Cross-check between related items indicates high persistence across the questions. Summarized in a table 2 are the main content and short description of the questionnaire as well as numbers of respondents giving supporting ideas on each item from 278 participants.

All of the statements, including the common misconceptions about NOS are averagely supported by Vietnamese. Instead of the 8 aspects of NOS proposed by Lederman & Lederman (2014), we separate the “Subjective NOS and/or theory laden NOS” into two independent elements so that it will be clearer with more details to be reported. The 9 NOS aspects with its description and the respective questionnaire item code were presented in appendices table 3. Noted that for an easier interpretation of the participants’ ideas and a better understanding of Vietnamese views of NOS, the so-call aspect “Partly subjective and/or theory-laden NOS” of Lederman & Lederman (2014) was separated into two isolated aspects.

All in all, generally the instrument satisfies the requirement of this study, that is, it can reveal the participant's personal views of NOS, with Vietnamese cultural identity. Inner cross-validation among the response shows high consistency in the participants' view. In comparison with the original VNOS-C of Lederman, the VN-VNOSQ is more effective to use in the Vietnam context since it provides more data to evaluate and cross-check, and, lower the number of missing answers as in the case of the original within a more limited time.

It should be noted that although this questionnaire provides some given options under the Likert scales, it should be validated as a qualitative tool instead of being considered as a quantitative tool because the most valuable ideas are considered not from the Likert score but the supporting ideas. The supporting ideas should be the main channel to decide a view is informed or alternative. In general, VN-VNOSQ measures the views of different people, and different ones can have significantly different views so that we cannot compare nor contrast among people. In other words, we cannot run the Cronbach's alpha reliability and other correlation tests. The conclusion on a view of a NOS aspect was drawn from not only the Likert scale indicators but also from the supporting ideas and explanations. Therefore, VN-VNOSQ needs to be analysed in the same manner as a qualitative assessment tool to reveal the views of humans. The researcher needs to validate the tool manually by comparing the checked score with the supporting ideas, and across the related items. Member checking should be applied to maintain the reliability of the interpretation process.

### CONCLUSION

Instead of using a provided tool robotically, the paper calls for more critical employment of the tool based on the consideration of social and cultural context. This is not only important in the case of Vietnam but also in any new circumstances. High appreciation of the context will guide researchers to most effectively generate data for our research. Most importantly, if we appreciate the cultural and social context and the freedom in human views, there will be more than just "naïve" and "informed" views of nature of science. The alternative ideas contribute to the identity of the culture which should be appreciated by any science researchers, educators, and teachers.

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## APPENDICES

**Table 1.** Vietnamese View of Nature of Science Questionnaire (VN-VNOSQ)

Code	Statement	Strongly Disagree	Dis-agree	Un-certain	Agree	Strong-ly Agree
Q1-1	Science is completely objective. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-2	Science can solve all problems. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-3	Scientific knowledge is the truth. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-4	Scientific knowledge although is durable, will change over time. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-5	Science relies entirely on the observations of the natural world. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-6	Science relies heavily but not entirely on the observations of the natural world. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-7	Science is conducted by a single universal method (commonly used for everyone). <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-8	The development of science always requires experiments. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-9	Science is always based on accurate data. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-10	Scientific knowledge is “created” (human creates knowledge) <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-11	Scientific knowledge is “discovered” (knowledge exists outside and human find it) <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-12	The development of science requires knowledge sharing in the community. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-13	Scientific ideas are affected by the circumstances of history and society. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q1-14	Science is universal – identical in all over the world. <i>Supporting ideas:</i>	-2	-1	0	1	2
Q2: Is science affected by the social and cultural traditions in which it is practiced?						
<input type="checkbox"/> No, not affected. <input type="checkbox"/> Yes, a little <input type="checkbox"/> Yes, a lot <input type="checkbox"/> Unsure						
Reason: _____						



Table 1. (Cont')

Code	Statement	Strongly Disagree	Dis-agree	Un-certain	Agree	Strongly Agree
Q3-1	Theories will become laws if we have more evidences to prove their rightfulness.	-2	-1	0	1	2
Q3-2	Laws can become theories if the coverage is expanded.	-2	-1	0	1	2
Q3-3	Laws have higher positions than theories in science.	-2	-1	0	1	2
Q3-4	Theories can be changed and replaced.	-2	-1	0	1	2
Q3-5	Laws cannot be changed and replaced.	-2	-1	0	1	2
Q3-6	Scientists develop theories as a basement to develop laws.	-2	-1	0	1	2

Other(s): \_\_\_\_\_

Q4. Function of scientific laws is: \_\_\_\_\_

Q5. Function of scientific theories is: \_\_\_\_\_

Q6: Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) in motion around the nucleus. *How certain are scientists about the structure of the atom?*

Completely certain      About \_\_\_\_\_% certain       Not certain       Unsure

Reason: \_\_\_\_\_

Q7: What specific evidence do you think scientists used to determine what an atom looks like?

Code	Statement	Strongly Disagree	Dis-agree	Un-certain	Agree	Strongly Agree
Q7-1	Experimental evidence and/or observed image	-2	-1	0	1	2
Q7-2	Logical Reasoning	-2	-1	0	1	2
Q7-3	Creativity and imagination	-2	-1	0	1	2
Q7-4	Experience and previous knowledge	-2	-1	0	1	2

Other(s): \_\_\_\_\_

Q8: In your opinion, do scientific models reflect the exact reality or not?

Totally exact       Unsure       Not totally exact

Reason: \_\_\_\_\_

Q9: There are several theories about the origin of the Moon, for instance the "Fission from Earth" hypothesis, the "Formation at the same time as Earth" hypothesis, and the "giant impact" hypothesis. *How are these different conclusions possible if scientists in every group have access to and use the same set of data to derive their conclusions?*

Q10: Do scientists use their creativity and imagination during these investigations?

Yes       Unsure       No

• If yes, then at which stages of the investigations:

Planning and design       Data collection       After data collection

Why and how do scientists use (or should not use) imagination and creativity? \_\_\_\_\_

Q11: In your opinion, what is the best method in scientific investigation? *(can choose more than one answer)*

Must have experiment.

Must follow the step-by-step scientific method.

Use the best technical means that are possible.

There are no single best method for all problems.

Other(s) and/or reason: \_\_\_\_\_

**Table 2.** Numbers and Percentage of Supporting or Alternative Ideas Received from 278 Completed Forms

Item Code	Content	Short Description	Main NOS Feature	No. of Respondents
Q1-1	Science is completely objective.	Statement – Likert scale	Tentative	115
Q1-2	Science can solve all problems.	Statement – Likert scale	Tentative	137
Q1-3	Scientific knowledge is the truth.	Statement – Likert scale	Tentative	106
Q1-4	Scientific knowledge although is durable, will change over time.	Statement – Likert scale	Tentative	104
Q1-5	Science relies entirely on the observations of the natural world.	Statement – Likert scale	Empirical	113
Q1-6	Science relies heavily but not entirely on the observations of the natural world.	Statement – Likert scale	Empirical	85
Q1-7	Science is conducted by a single universal method (commonly used for everyone).	Statement – Likert scale	Scientific method	98
Q1-8	The development of science always requires experiments.	Statement – Likert scale	Scientific method	107
Q1-9	Science is always based on accurate data.	Statement – Likert scale	Theory-laden	99
Q1-10	Scientific knowledge is “created” (human creates knowledge)	Statement – Likert scale	Creative	101
Q1-11	Scientific knowledge is “discovered” (knowledge exists outside and human find it)	Statement – Likert scale	Creative	78
Q1-12	The development of science requires knowledge sharing in the community.	Statement – Likert scale	Social and cultural	95
Q1-13	Scientific ideas are affected by the circumstances of history and society.	Statement – Likert scale	Social and cultural	81
Q1-14	Science is universal – identical in all over the world.	Statement – Likert scale	Social and cultural	108
Q2	Is science affected by the social and cultural traditions in which it is practiced?	Multiple choices combine open-ended part	Social and cultural	170
Q3	Is there a difference between a scientific theory and a scientific law?	6 Likert scale statements + open-ended part	Theories and laws	13
Q4	Function of scientific laws is: _____	Short answer	Theories and laws	193
Q5	Function of scientific theories is: _____	Short answer	Theories and laws	190
Q6	How certain are scientists about the structure of the atom?	Multiple choices combine open-ended part	Tentative	118
Q7	What specific evidence do you think scientists used to determine what an atom looks like?	4 short answers - Likert scale + open-ended part	Observation – Inference – theory-laden	10
Q8	In your opinion, do scientific models reflect the exact reality or not?	Multiple choices combine open-ended part	Tentative	156

Q9	How are different conclusions possible if scientists in different groups have access to and use the same set of data to derive their conclusions?	Open-ended question	Subjective – Inference	205
Q10	Do scientists use their creativity and imagination during these investigations?	Multiple choices combine open-ended part	Creative	201
Q11	In your opinion, what is the best method in scientific investigation?	Multiple choices combine open-ended part	Scientific method	44

**Table 3.** NOS Aspect Relate to the VN-VNOSQ Items with the Description

<b>NOS Code</b>	<b>NOS Description (The Number in the Parentheses is the Code of the Item)</b>
1	Scientific tentativeness Science cannot solve all problems (Q1-2) Scientific knowledge is not the truth (Q1-3) Scientific knowledge although is durable, will change over time (Q1-4) Science is not completely certain (Q6)
2	Empirical NOS Science relies heavily but not entirely on the observations of the natural world (Q1-5, Q1-6)
3	Observation and inference Scientists use their observation as a channel of data (Q1-5, Q7-1) Scientists need inference from their previous knowledge and experience, logical reasoning, imagination and creativity (and so on) to draw their conclusion (Q1-6, Q7-2, Q7-3, and Q7-4)
4	Science is partly subjective Science is not completely objective (Q1-1) Scientific models do not reflect the exact reality (Q8) Scientists have different perspectives, different previous knowledge and experience, their own ways of inference... (Moon – Q9)
5	Scientific knowledge is theory-laden Science is not always based on data (Q1-9) We explain everything that we perceive through our prior understanding of the theories and other concepts (Q7-4)
6	Science is creative and imaginative Scientific knowledge is “created” (human creates knowledge) (Q1-10) rather than “discovered” (knowledge exists outside and human find it) (Q1-11) Scientists use their creativity and imagination during their investigations in every step of the investigations (Q9, Q10)
7	Social and cultural impacts on science Science affected by the social and cultural traditions (Q2) The development of science requires knowledge sharing in the community (Q1-12) Scientific ideas are affected by the circumstances of history and society (Q1-13) Science is not identical in the world (Q1-14)
8	Scientific theories and laws Theories will not become laws even if we have more evidences to prove their rightfulness. (Q3-1) Laws will not become theories even if the coverage is expanded. (Q3-2) Laws and theories have their own roles and positions in science. (Q3-3) Both laws and theories can be changed and replaced (Q3-4 and Q3-5) Scientists do not develop theories as a basement to develop laws. (Q3-6) Scientific laws describe how a phenomenon occurs. (Q4) Scientific theories explain why a phenomenon occurs. (Q5)
9	Scientific method There is no single universal method that commonly used for everyone (Q1-7) Science does not always require experiments (Q1-8) There is no single best method for all problems (Q11)