Comparison of Nature of Science Profile in Indonesia, Malaysia, and Singapore Secondary Science Textbooks: Case of Electricity Lesson

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Abstract: Nature of Science is a significant element in science education, especially for the linkages to scientific literacy. As one of an educational support for both teachers and students, textbooks become crucial for teaching and learning. Textbooks may elicit NOS understanding for students and guide teacher to deliver NOS understanding. The way to make better process and outcome, integration of NOS into the textbooks comprehensively is crucial. To get a better understanding of NOS within the diverse framework, an inclusive framework is needed to get better understanding, thus, Family Resemblance Approach is chosen. This study aims to identify the profile of NOS integration and NOS quality in secondary science textbooks by comparing different textbook from three neighboring countries (Indonesia, Malaysia, and Singapore). Descriptive research design with content analysis method conducted to identify the documents using the Family Resemblance Approach to NOS as the analytical framework. The results show that Indonesian textbooks presenting most abundance of NOS, but contain most materials delivered and the quality is mainly at low level. Malaysian textbooks contain the least representation but contain well proportion for the quality and materials presented. Singapore textbooks is least materials with abundance of NOS and consist of high-level quality of NOS. This may lead the conformity of the significance of textbooks elicited students understanding of NOS.

Keywords: Nature of Science; Secondary Science Textbooks; Family Resemblance Approach

Introduction

Science educators as well as researchers recognize the significance of the Nature of Science (NOS) so that curricula and standard documents are widely introduced in some countries in the world (NGSS, 2013). At this time, a basic understanding of NOS is also considered as the main pillar of society's scientific literacy (Clough, 2018; NGSS, 2013; Schleicher, 2019). NOS has become the center of attention regarding its relation to scientific literacy, especially with the existence of the PISA science test which was initiated to measure students' scientific literacy (OECD, 2019). Logically, a good understanding of NOS will help these interactions occur even with a more solid character and a greater potential impact on the world of education (Laherto et al., 2018). Scientific literacy has become one of the main objectives in science education (NGSS, 2013). Different interpretations of Nature of Science lead to a broad and diverse yet functional understanding of science for general educational purposes (Irzik & Nola, 2014). No matter what the target of scientific literacy is, finding out "what constitutes science" and "what kind of science should be taught" has become a major question in science education (Abd-El-Khalick, 2012). The line of research that focuses on these fundamental questions about science is the "Nature of Science".

In line with the context in which scientific literacy can be improved by understanding NOS, Indonesia is only crawling towards that direction with an implicit NOS approach. Standard documents in several developed countries have explicitly written NOS as part of a program to improve scientific literacy(NGSS, 2013). Indonesia itself does not explicitly state NOS as a component of scientific literacy. It is stated in the book Master Design of the National Literacy Movement that the foundation of scientific literacy is "The ability to use scientific knowledge and principles to understand the environment and test hypotheses." (Satgas Gerakan Literasi Sekolah Kemendikbud, 2019) which the statement contains some aspects of NOS.

We can see quite different results from the PISA scores of neighboring countries such as Malaysia and Singapore. Compared to the dismal history of PISA Indonesia, Malaysia can at least be included at level 2 with a ranking of 48 out of 78 countries. Meanwhile, Singapore managed to outperform PISA by ranking the 2nd highest (top Level 3) under China (Schleicher, 2019). Although it did not reach the Level 4 category, of course Singapore's achievement is splendid. Singapore is in the high ranks among countries with other High-Performing Education Systems such as Japan, Finland, UK, US, and so on (Deng & Gopinathan, 2016).

Given the complexity of NOS, a list of NOS features cannot be exhaustive, but we can offer a summary of what science is all about. A recent depiction of NOS that focuses on the interconnection of various aspects of NOS commonly known as the Family Resemblance Approach (FRA) originally proposed by philosophers of science Irzik and Nola in 2011 and was widely developed and adapted by science education researchers Erduran and Dagher (2014). FRA shows a wide range of scientific practices, methodologies, goals and values, social norms and aspects that contextualize and frame scientific knowledge in a unique way but still embrace each discipline (Kaya & Erduran, 2016). FRA's idea of NOS is based on the idea of Family Resemblance from Wittgenstein's original work. The main idea of Wittgenstein is that a complex concept can be understood as a network of interrelated equations or similarities (Irzik & Nola, 2014).

As for the NOS perspective, the characteristics of the material that are suitable for teaching NOS are materials that can describe the aspects of NOS explicitly (Abd-El-Khalick, 2012). NOS is also seen as being able to be effectively taught with authentic material linkages and can be delivered as if students could "discover or develop" the theory as the scientist who discovered it (McComas & Clough, 2020). In addition, material that can effectively convey the NOS concept is material that is closely related to the development of historical cases involving the development of the scientific method, related to the myths that exist in everyday life and others (McDonald & Abd-El-Khalick, 2018). Based on some of these reviews and the content of the Indonesian science curriculum secondary school material, we can find all these things in the electrical material, namely the history and development of the science of electricity, as well as the concepts that able to integrate them such as magnetism, technology, and energy.

Decisively, a question arose about how the comparison of books formed from the education system in Indonesia, namely the 2013 Curriculum Science textbooks with textbooks from countries at different levels from Indonesia such as level 2 and 3 categories, especially Malaysia (level 2) and Singapore (level 3). This study will be limited to the proportion of NOS categories that were present to each countries' books excluding activities section because the Singaporean books have separate books for the science activity that currently unavailable.

This paper aims to identify the NOS profile by means of categories composition that present within the books, as well as the quality of the representation. To this date, research involving Indonesian books in the context of international comparison is scarce. This is certainly an opportunity that must be filled with an empirical approach. Scientific research to present information related to textbooks on NOS with an inclusive approach is also very crucial for the advancement of science, especially in the field of NOS and its relation to pedagogical aspects which are expected to improve the quality of scientific literacy of students.

Method

This research is a descriptive study with content analysis method. This method was chosen because the object of research in this study is a document in the form of a textbooks that will be studied about its NOS representations without providing any modifications, so that this condition matches the criteria. In content analysis, an analytical framework is needed that is used as a lens in the investigation to obtain data that is in accordance with the research objectives. The analytical framework used is the Family Resemblance Approach as the NOS categories that comprises of three main aspects and 11 categories. FRA captures the very general characterization of key science-related categories in a broad sense. In other words, FRA is more inclusive of various aspects in the description of its knowledge (Dagher & Erduran, 2016). More detail on FRA are presented on Table 1.

Table 1. Description of the FRA categories (Erduran et al., 2019)

Categories	Description
Cognitive-Epistemic Aspect	
Scientific Aims and Values	The scientific enterprise is underpinned by adherence to a set of values that guide scientific practices. These aims and values are often implicit and they may include accuracy, objectivity, consistency, skepticism, rationality, simplicity, empirical adequacy, prediction, testability, novelty, fruitfulness, commitment to logic, viability, and explanatory power.
Scientific Practices	The scientific enterprise encompasses a wide range of cognitive, epistemic and discursive practices. Scientific practices such as observation, classification, and experimentation utilize a variety of methods to gather observational, historical, or experimental data. Cognitive practices such as explaining, modeling, and predicting are closely linked to discursive practices involving argumentation and reasoning.
Scientific Methods	Scientists engage in disciplined inquiry by utilizing a variety of observational, investigative, and analytical methods to generate reliable evidence and construct theories, laws, and models in a given science discipline, which are guided by particular methodological rules. Scientific methods are revisionary in nature, with different methods producing different forms of evidence, leading to clearer understandings and more coherent explanations of scientific phenomena.
Scientific Knowledge	Theories, laws and models (TLM) are interrelated products of the scientific enterprise that generate and/or validate scientific knowledge, and provide logical and consistent explanations to develop scientific understanding. Scientific knowledge is holistic and relational, and TLM are conceptualized as a coherent network, not as discrete and disconnected fragments of knowledge.
Social-Institutional Aspects	
Professional Activities	Scientists engage in a number of professional activities to enable them to communicate their research, including conference attendance and presentation, writing manuscripts for peer-reviewed journals, reviewing papers, developing grant proposals, and securing funding.
Scientific Ethos	Scientists are expected to abide by a set of norms both within their own work, and during their interactions with colleagues and scientists from other institutions. These norms may include organized skepticism, universalism, communalism and disinterestedness, freedom and openness, intellectual honesty, respect for research subjects, and respect for the environment.
Social Certification	By presenting their work at conferences, and writing manuscripts for peer-reviewed journals, scientists' work is reviewed and critically evaluated by their peers. This form of social quality control aids in the validation of new scientific knowledge by the broader scientific community.
Social Values	The scientific enterprise embodies various social values including social utility, respecting the environment, freedom, decentralizing power, honesty, addressing human needs, and equality of intellectual authority
Social Organization and Interactions	Science is socially organized in various institutions including universities and research centers. The nature of social interactions among members of a research team working on different projects is governed by an organizational hierarchy. In a wider organizational context, the institute of science has been linked to industry and the defence force.
Political Power structures	The scientific enterprise operates within a political environment that imposes its own values and interests. Science is not universal, and the outcomes of science are not always beneficial for individuals, groups, communities, or cultures.
Financial Systems	The scientific enterprise is mediated by economic factors. Scientists require funding in order to carry out their work, and state and national level governing bodies provide significant levels of funding to universities and research centers. As such, these organizations have an influence on the types of scientific research funded, and ultimately conducted.

As the lenses of the study, the FRA description and fundamental theories about FRA were read carefully so comprehension about the categories were clear. First step on the data collection is reading the books carefully while identifying for its electricity lesson material, then it is marked for the page. The electricity lesson material can be in the form of narrative text, picture, diagram, or any representation that gives information about electricity concept or eliciting the electricity concept indirectly if it was integrated in other lesson. After that, the material then analyzed to identify its NOS representations that it may be represented as any form whether text or any visual representation. In this case, one part of the lesson may represent more than one NOS categories. Finally, the quality of the representation then graded from 1- 3 for each representation with the criteria on Table 2.

The reliability of the inter-rater as well as for the NOS representation and quality grades were achieved by discussion until all researchers achieve the level of attaining agreement on the sample pages. Any different views were solved by doing the same principle. After the sample review process to attain the reliability, the rest of the identification done by first researcher while any further discussion may happen during the whole process.

Table 2. NOS Representation Criterion

NOS Quality	Description
Superficial	Indicates NOS representation is superficially mentioned, implied, or skipped
Detail	Show the NOS representation accompanied by some details, or provide supporting documents such as pictures, diagrams, and graphs.
Exemplary	Refers to the NOS representation in an exemplary way, with explicit reference to the context and relevant to the students.

The total of books identified in this study are 13 books. All the books were priorly identified as the official textbooks endorsed by the government of the country to be used in the scale of national on the secondary school education. The detailed information of the textbooks is presented on Table 3.

Table 3. Secondary science textbooks in the study

Book Title	Publisher	Year
Ilmu Pengetahuan Alam, Grade 7 (first and second semester)	Center for Curriculum and Books, Kemendikbud (Indonesia)	2018
Ilmu Pengetahuan Alam, Grade 8 (first and second semester)		2017
Ilmu Pengetahuan Alam Grade 9 (first and second semester)		2017
Science Form 1	Karangkraf Network sdn.bhd. (Malaysia)	2016
Science Form 2		2017
Science Form 3		2018
Science for Lower Secondary Express/Normal (Academic) 1A & 1B	Marshall Cavendish (Singapore)	2021
Science for Lower Secondary Express/Normal (Academic) 2A & 2B		2021

Result and Discussion

General NOS Representation

Based on the study, we can find the integtration of electricity lesson material thoroughut the books whether implicitly or explicitly. The details on the general finding of the NOS representation of the textbooks are presented on Table 4, 5, & 6.

Table 4. General NOS profile (Indonesia)

Textbook	7A	7B	8A	8B	9A	9B	Sum
Representation	13	3	10	3	111	85	225
Representation percentage (%)	5.8	1.3	4.4	1.3	49.3	37.8	100
Identified page	8	2	5	2	47	32	96
Page percentage (%)	8.3	2.1	5.2	2.1	49.0	33.3	100

As it may seem in Table 4, the chapters that providing the electricity lesson materials explicitly, or presenting the material as a complete chapter was found on the 9A book, while 9B contain chapter about technology that presenting various information of electrical energy. Textbook 9B as a chapter that did not contain an explicit chapter about electricity presenting a signifcant amount of the representation found as 1/3 of the total representation found. Half of the total (49%) of the representation found on textbook 9A as the main textbook that deliver electricity chapter explicitly. The textbook of 7th and 8th grade containing a considerable amount of representation about (17.7%) that almost 1/5 of the total. With the total page of 96 and 225 representations, we may infer that in one page there are at least 1 to 2 reprentation with most of the page contain only one repsentation per page overally.

Table 5. General NOS profile (Malaysia)

Textbook	7	8	9	Sum
Representation	6	40	67	113
Representation percentage	5.3%	35.4%	59.3%	100%
Identified page	4	19	31	54
Page percentage	7.4%	35.2%	57.4%	100%

On Table 5, the representation in a big proportion found mainly on grade 8 and 9 textbook. Both books presenting chapters of electricity explicitly with the same chapter title and theme that is "electricity and magnetism". Both books combined presenting more than 90% of the representation while grade 7 textbook containing the smallest proportion less than 1/10 of the total. With the total page of 54 and 113 representations, we may infer that in one page there are at least 1 to 2 reprentation with most of the page contain only one repsentation per page overally.

Table 6. General NOS profile (Singapore)

Textbook	7A	7B	8A	8B	Sum
Representation	4	9	40	101	154
Representation percentage	2.6%	5.8%	26.0%	65.6%	100%
Identified page	3	3	10	28	44
Page percentage	6.8%	6.8%	22.7%	63.6%	100%

For Singapore, as it described on Table 6, the main chapter of the electricity presented on textbook 8B presenting electricity as systems theme. Textbook 8A presenting chapter of energy that presenting rich information about electrical energy. Majority of the representation identified on the grade 8 textbooks as 86.3% of the total while the rest are implicitly integrated on the grade 7 textbooks containing the smallest proportion less than 1/10 of the total. With the total page of 44 and 154 representations, we may infer that in one page there are at least 3 to 4 reprentation in overal.

In comparison, Indonesian textbooks delivering the most content of all with the total of 96 pages but contain

far different with Singaporean textbooks that it may only deliver half of the content but deliver more representation of NOS. On the other hand, generally Indonesian and Malaysian textbooks are seems to be similar in ratio, but Malaysian textbooks deliver less content pages for the whole secondary school. It need to be noted that lower secondary school for Singapore only two years, means that it is one year different than Indonesia and Malaysia but the students are at the same range of age. Considering the years of study and exclusion of textbook other than the main book that that represent NOS, Indonesia delivers the highest amount of content with 79 pages to study in a year. On the other side, Singapore textbooks deliver the significantly less content than Indonesia for about 38 pages for a year. Lastly, Malaysia deliver least content about 50 pages for two year, means it was only about 25 pages per year for rough calculation. Visualization of the data provided on Figure 1 for more convenience presentation on the general perspective.
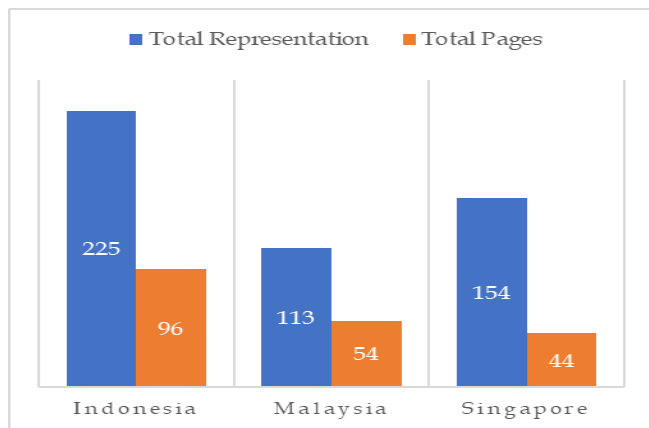

Figure 1. General NOS representation comparison

NOS Categories and Quality

In this section, the categories are identified in depth that the process inquire the detail of each main idea that presenting discrete concept for every pages. The case is applied especially in the scientific knowledge categories that it is extended to the details that support theories, laws, dan models, causing the number of representations is visibly plentous. There are also representation that may include into more than one categories that were similar resulting some results are considered to be included into certain categories than the others. As example, the values of respecting the environment may included into the scientific ethos or social values, since the representation do not directly related with scientific practices it is inserted to the social values instead of the scientific ethos. For the general result, all of the textbook do not present the categories of scientific ethos and social certification. The detailed result of the NOS categories and its quality are presented in Table 7 - 10.

Table 7. NOS Categories and Quality (Indonesia)

Categories	Quality			Sum
	1	2	3	
Scientific Aims and Values	7	1	4	12
Scientific Practices	14	3	0	17
Scientific Methods	1	0	0	1
Scientific Knowledge	87	22	11	120
Professional Activities	3	0	4	7
Scientific Ethos	0	0	0	0
Social Certification	0	0	0	0
Social Values	42	12	1	55
Social Organization and Interactions	3	1	0	4
Political Power structures	3	0	0	3
Financial Systems	6	0	0	6
Total	166	39	20	225

Table 8. NOS Categories and Quality Percentage (Indonesia)

Categories	Quality (%)			Mean
	1	2	3	(%)
Scientific Aims and Values	58.3	8.3	33.3	5.3
Scientific Practices	82.4	17.6	0	7.6
Scientific Methods	100	0	0	0.4
Scientific Knowledge	72.5	18.3	9.2	53.3
Professional Activities	42.9	0	57.1	3.1
Scientific Ethos	0	0	0	0
Social Certification	0	0	0	0
Social Values	76.4	21.8	1.8	24.4
Social Organization and Interactions	75	25	0	1.8
Political Power structures	100	0	0	1.3
Financial Systems	100	0	0	2.7
Total	73.8	17.3	8.9	100

Table 7. NOS Categories and Quality (Malaysia)

Categories	Quality			Sum
	1	2	3	
Scientific Aims and Values	1	0	0	1
Scientific Practices	2	0	4	6
Scientific Methods	0	1	1	2
Scientific Knowledge	35	27	17	79
Professional Activities	1	0	0	1
Scientific Ethos	0	0	0	0
Social Certification	0	0	0	0
Social Values	8	4	1	13
Social Organization and Interactions	0	1	1	2
Political Power structures	5	1	2	8
Financial Systems	0	1	0	1
Total	53	36	24	113

The noteable result is the main representations of the scientific knowledge category of Indonesian testbooks that makes up more than a half of the total representations (53.3%). As cognitive-epistemic aspect (category 1-4), it represents 66.7% of the total while the rest (33.3%) representing the social-institutional aspects that are concentrated on the social values that contain

24.4% of the total. The proportion of the quality is dominated by level 1 NOS quality that made up more than 7/10 of the whole representations with the level 3 only found less than 1/10 and the rest is on the level 2.

Table 8. NOS Categories and Quality Percentage (Malaysia)

| Categories | Quality (%) | | | Mean |
	1	2	3	(%)
Scientific Aims and Values	100	0	0	0.9
Scientific Practices	33.3	0	66.7	5.3
Scientific Methods	0	50	50	1.8
Scientific Knowledge	44.3	34.2	21.5	69.9
Professional Activities	100	0	0	0.9
Scientific Ethos	0	0	0	0
Social Certification	0	0	0	0
Social Values	61.5	30.8	7.7	11.5
Social Organization and Interactions	0.0	50	50	1.8
Political Power structures	62.5	12.5	25.0	7.1
Financial Systems	0	100	0	0.9
Total	46.9	31.9	21.2	100

Table 9. NOS Categories and Quality (Singapore)

| Categories | Quality | | | Sum |
	1	2	3	
Scientific Aims and Values	1	1	5	7
Scientific Practices	4	0	1	5
Scientific Methods	0	0	0	0
Scientific Knowledge	23	55	13	91
Professional Activities	2	1	0	3
Scientific Ethos	0	0	0	0
Social Certification	0	0	0	0
Social Values	13	21	3	37
Social Organization and Interactions	2	1	0	3
Political Power structures	3	2	1	6
Financial Systems	2	0	0	2
Total	50	81	23	154

It can be seen from Table 8, the Malaysian textbooks contain about 70% scientific knowledge categories.

Regarding the cognitive-epistemic aspects (1st-4th categories) other than scientific knowledge contain 8% of the total, while the sosial-institutional aspect (5th – 11th categories) mainly presented in social values and political power structures that made up 18.6% of the total representation. In the quality side, the high level of quality (level 2 and 3) contained as more than half of the total representation (53%) and the rest is level 1.

Table 10. NOS Categories and Quality Percentage (Singapore)

| Categories | Quality (%) | | | Mean |
	1	2	3	(%)
Scientific Aims and Values	14.3	14.3	71.4	4.6
Scientific Practices	75	0	25	3.2
Scientific Methods	0	0	0	0
Scientific Knowledge	25.3	60.4	14.3	59.1
Professional Activities	66.7	33.3	0	1.9
Scientific Ethos	0	0	0	0
Social Certification	0	0	0	0
Social Values	35.1	56.8	8.1	24
Social Organization and Interactions	66.7	33.3	0	1.9
Political Power structures	50	33.3	16.7	3.9
Financial Systems	100	0	0	1.3
Total	32.5	52.6	14.9	100

Based on Table 10, scientific knowledge also made up the main composision of the total that made up more than half of the total (59.1%). Regarding cognitive-epistemic aspect, the scientific method was not identified in the textbook. The composition of the sosial-institutinal aspects made up 31.1% of the total that mainly presented as social values category (24%). Regarding the quality of the representation, the high-quality representation is almost made up 7/10 of the total (67.5%).
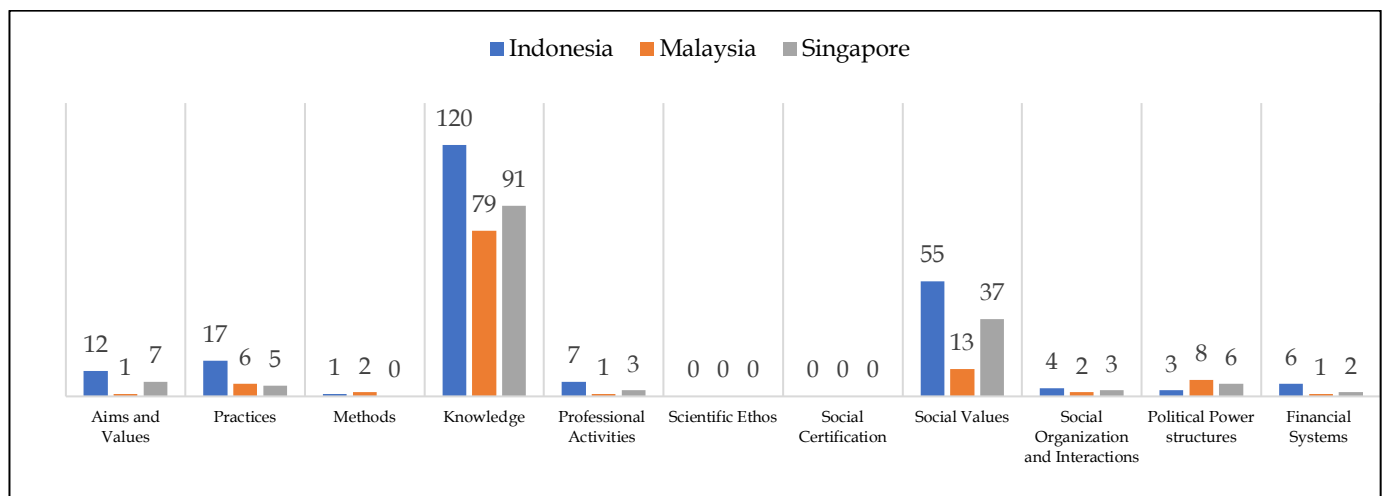

Figure 2. NOS categories profile comparison

For better understanding about the results to be compared, a bar graph produced for the Figure 2 & 3. The occurrence or pattern of the textbooks are clear that most of the textbooks saturated in the cognitive-epistemic aspect (mainly scientific knowledge) and less found in social-institutional aspect (mainly social values). In this study the category of social certification is not found even once, while the category of scientific ethos may implicitly present but the characteristic is suit more to social values, since the representation not explicitly related to scientific practices but more to social issue.
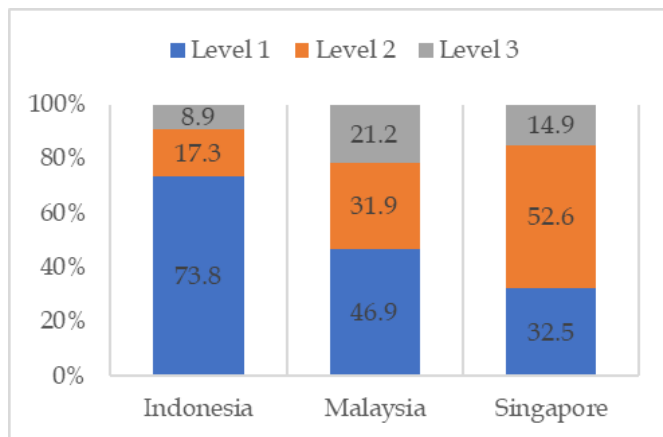

Figure 3. NOS quality profile comparison

Briefly, Indonesian textbooks seems to present the more representation and rich categories of NOS. However, Indonesian textbooks also provided in most pages of all textbooks. The quality of NOS in Indonesia textbook also mainly on level 1, which theoretically less expected to be presented on textbook. While the level 2 and 3 that expected to be found more was less. A different case with Malaysian textbook, the representation is the least compared to all of the other books. However, the composition is mainly constructed of high-level quality of representation of level 2 and 3 that is more than half of the total. While Singaporean textbooks are a lot denser in term of the representation that it presented on the least total pages that was identified in this study. Most of the representation for almost 7/10 of the total is high level quality of NOS.

This results infer a similar outcomes from the other study. Salem (2021), in comparing French, American and Lebanese science textbooks showing the discrete composition of the categories that saturated on the cognitive-epistemic aspects. Furthermore, the proportion of the quality may also similar that some textbook may represent mostly on level 1 or 2 and least on level 3. Saouma BouJaoude et al. (2018), also found out that the aspect of social-institutional is a lot less than the cognitive-epistemic aspect. Park et al. (2014), found similar result about the proportion of the categories in the context of textbook tasks.

These results showing the conformity of Singapore of the top-tier in achieving scientific literacy assessment, as well as Indonesia as the low-tier. Malaysian textbooks represent good quality of NOS composition, the lower frequency resulted that a lot of whole page pictures were presented on Malaysian textbooks. Overall, Indonesian textbooks showing its potential to eliciting NOS understanding, but it is weighed by most lesson material as compared to Malaysia and Singapore. The study is limited to the exclusion of science activity within the book, so the interpretation and conclusion drawn from this study is limited by this context.

Conclusion

Indonesian textbooks represent generally the most representation of NOS categories but it also containing the most lesson maerial, while the quality is mainly on low level. Malaysian textbooks presenting a lot less representation and material than Indonesia but providing better composition at high NOS representation quality. Singaporean textbooks as it conformity with the educational system quality, providing less pages, but denser representation of NOS and more high-quality NOS representation in compared to others. It may lead to the conformity of the significance of the textbooks to increase students understanding of NOS.

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