International Journal of Learning, Teaching and Educational Research
Vol. 21, No. 11, pp. 426-442, December 2022
https://doi.org/10.26803/ijlter.21.11.24
Received Aug 30, 2022; Revised Nov 21, 2022; Accepted Dec 5, 2022

Rwandan Senior Secondary Physics Students' Views on Nature of Science

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Abstract. Although the nature of science (NOS) is recognized worldwide as an important aspect of promoting the understanding of science subjects in schools but very little research has been conducted in this regard in the Rwandan context. This study investigates the status of Rwandan senior secondary physics students' views on NOS aspects. The instrument for data collection in this study is made up of 30 items adapted from "Views of Nature of Science-B"; "Student Understanding of Science and Scientific Inquiry (SUSSI)"; and "Views of Nature of Science-C (VNOS-C)". After establishing the reliability of the instrument, we administered this questionnaire to 148 senior secondary physics students from four schools (i.e. randomly selected two boarding schools and two day schools) from Kicukiro and Kayonza districts. Frequency, mean, and standard deviation were calculated, and a *t*-test was used as part of the data analysis. The findings of this study indicate that many of the students have strongly held and naïve views about all targeted NOS aspects. The naïve views are predominantly related to the tentative nature of science; empiricism; the relationship between scientific theories and laws; social contexts in knowledge construction; and scientific methods, compared to other remaining targeted NOS aspects which are observation and inferences; and imagination and creativity. The study revealed that, overall, students' understanding of NOS is not influenced

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by gender or school location. However, a more detailed look shows slight variations between male and female students on some items.

Keywords: Nature of Science (NOS); senior secondary physics students; science; Views of Nature of Science (VNOS); naïve views

1. Introduction

Nature of science (NOS) and its awareness among secondary school students are necessary in the present era, particularly its representation in the science curriculum. This is because of its role in increasing the interest of students in learning science and making it their career, developing critical thinking, and helping learners to apply what they have learned (McComas, 2002; Rana et al., 2015). In addition to this, understanding NOS helps students in building a strong capacity for making informed decisions about scientific enterprises (NRC, 2012). However, several research studies have indicated that secondary school students have a steady and negative attitude toward science and harbor naïve views on the understanding of NOS (Toma et al., 2019; Vázquez-Alonso et al., 2014; Yoon et al., 2014).

One of the vital components in realizing an effective 'understanding of science' is promoting the understanding of NOS and to improve adequate views of NOS (Billingsley & Fraser, 2018; Das et al., 2019). This is because NOS clearly describes the historical, social, and philosophical perspectives of science (Lederman, 2007). NOS informed views refer to the abilities of students to understand, evaluate scientific knowledge and develop deep learning in scientific methods and processes (Liang et al., 2008).

Understanding and improving students' views on NOS (Lederman et al., 2002) have been of significant interest and researchable topics for science education researchers (NRC, 2012; NGSS Lead States, 2013; McComas & Nouri, 2016). Several attempts and interventions to improve students' views on NOS in USA (Abd-El-Khalick, 2013), Europe (Dagher & Erduran, 2017), and the Middle East (Nur & Fitnat, 2015) were put in place. For instance, UK introduced NOS standards in its science curriculum (Taber, 2008). Science curricula in countries such as USA and New Zealand not only focused on cognitive knowledge but also on the two standards that discussed NOS, which were identified among six aspects (Hipkins, 2012). However, apart from the lack of explicit NOS representation in teaching materials (Bugingo et al., 2022a; Caramaschi et al., 2022), research studies across the globe are still reporting an inadequate understanding of NOS among learners (Toma et al., 2019; Torres et al., 2015; Yoon et al., 2014). In addition to this, little attention is paid to the integration of NOS aspects, as observed in 24 Turkish middle science textbooks used from 1926 up to 2018 (Atakan & Akçay, 2022).

Contrary to the West, a very limited number of interventions and few initiatives on improving students' views about NOS and little effort in integrating NOS into science curricula in Africa were identified (Bugingo et al., 2022b; Ibrahim et al., 2009). For example, the South African natural science curriculum was identified as a model curriculum in the region to help learners to develop NOS understanding among students (Ogunniyi, 2006). Even though a few science curricula have been refined versus NOS representation, the implicit approach was reported as dominating (Upahi et al., 2020).

The deficit of NOS representation in science curricula and limited interventions on NOS aspects in teaching aids materials are worrisome in East African community countries (Kinyota, 2020; Kinyota & Rwimo, 2022; Munezero et al., 2022). For instance, in a study by Bugingo et al. (2022a), a very poor, vague representation of NOS was identified from four senior secondary school physics curricula from Rwanda, Burundi, Uganda and Tanzania. The literature on NOS understanding among students in the region is still low, particularly in the Rwandan context.

According to Ramnarain and Chanetsa (2016), it is vital to be aware of NOS understanding among students before designing a science curriculum or interventions that may ease NOS learning. Thus, the current study will contribute to understanding the learning and teaching of NOS in the region.

This study may inform science educationists in the region, particularly in Rwanda, which claims the promotion of a knowledge-based economy. A knowledge-based economy is not achievable without emphasis on the development of scientific enterprise. Implicitly, the existing secondary school curriculum in Rwanda provides an opportunity to make students aware of the nature of science (REB, 2015). However, the need for promoting explicit learning and teaching of NOS is a key requirement to building a strong educational system in Rwanda; to attaining and successfully sustaining high standards in science education; and overcoming a declining number of learners in science, technology, engineering, and mathematics (STEM) subjects and traditional instructional approaches (Uwizeyimana et al., 2018).

There is also no clear idea of how NOS is being integrated into the classroom if traditional teaching methods are still dominating in Rwandan classrooms (Ndihokubwayo, 2020), with little regard for the learners' acquisition of transferrable skills. In addition, in Rwanda, little is known from the literature about students' understanding of NOS. To address this issue, this study aimed to analyze the status of the understanding of NOS among senior secondary physics students in Kayonza and Kicukiro districts, Rwanda. Students’ understanding of NOS knowledge may guide a framework for the betterment of their understanding in this domain.

Research Questions

This study analyzed the responses of five senior physics students, on seven aspects of NOS, using-the following research questions.

1. What is the status of Rwandan physics students’ views towards NOS aspects?
2. Is the Rwandan physics students’ understanding of NOS affected by gender and school location?

2. Methodology

Research Approach Design

A mixed research approach was used to collect data. This approach was used due to its nature of combining the strengths of both quantitative and qualitative data. In this research design, the researchers gathered both quantitative and qualitative data for a deep understanding of NOS views among students (Creswell & Plano, 2011; Fraenkel et al., 2012). The main questionnaire on NOS views was used for collecting qualitative and quantitative data. After collecting the data from the field, the quantitative data were first analyzed and reported, which was complemented by qualitative data comparing the results in the discussion section. Furthermore, the interpretation was drawn from these findings.

Data Collection Instrument and Reliability

The *Views on Nature of Science Questionnaire* (VNOSQ) is made up of 30 items of close-ended questions to measure targeted NOS aspects (tentative; empirical; observation and inferences; relationship between scientific theories and laws; social and cultural contexts; creativity and imagination; and scientific methods). At least four items were used to measure each NOS aspect. While selecting and adapting the statements of the main questionnaire to assess students' views on NOS aspects, "Views of Nature of Science-B" (Lederman et al., 2002), "Student Understanding of Science and Scientific Inquiry (SUSSI)" (Liang et al., 2008), and "VNOS-C" (Lederman et al., 2002) for NOS were taken as reference.

Different items and open-ended questions developed by Lederman et al. (2002) and Liang et al. (2008) were adapted in this study; a sample is shown in Table 1. The 30 items were rated using the following five Likert scales: 1 = Strongly Disagree (SD); 2 = Disagree (D); 3 = Neutral (N); 4 = Agree (A); and 5 = Strongly Agree (SA). In addition, seven open-ended questions were also included in the questionnaire to measure the same targeted NOS aspects. The first six open-ended questions which related to tentative; empirical; observation and inferences; the relationship between scientific theories and laws, social and cultural embeddedness; creativity and imagination, and were adapted from VNOS-form C and D (Lederman et al., 2002). The seventh open-ended question was about scientific methods, adapted from SUSSI (Liang et al., 2008).

Table 1: A sample of adapted closed-ended items and open-ended questions

Part one: A sample of closed-ended items	Statements	Rating Scale				
		SD	D	N	A	SA
1	Some of the scientific theories produced by scientists changed after their development.	1	2	3	4	5
2	It is possible that scientific knowledge may change in the future.	1	2	3	4	5
3	Scientific theories may be completely replaced by new theories in light of new evidence.	1	2	3	4	5

4	With the help of technology development, scientific knowledge approaches absolute truth.	1	2	3	4	5
5	Scientific theories based on accurate experimentation will not be changed.	1	2	3	4	5
Part two: A sample of an open-ended question	With an example, explain why you think a scientific theory (for example, atomic theory) produced by scientists may be changed or do not change over time.					

Before administering the questionnaire for piloting, the two senior faculty members at our university helped to polish the instrument by checking the content, format, and ambiguous statements and questions. The reliability index was checked in the Rwandan context, and it was found to be 0.871, showing that the instrument is reliable. The validity was also checked by assessing the same NOS aspects for both quantitative and qualitative data. In addition to this, every participant in this study was given the same number of items and open-ended questions.

Participants and Data-Collection Procedures

Understanding NOS aspects require a high level of thinking about the epistemology of science. If the participants come from low grades, a good number of open-ended questions may be answered randomly and may lead to the divergence of reality and false results. Therefore, senior five (S5) students from the physics–chemistry–biology (PCB) combination were chosen. In Rwanda, senior five students are in mid-senior high school experience; students of this class (S5) are ready to respond to any co-curricular activity, as they are not being freshly introduced to secondary physics topics, and not preparing for national examinations. They are readily willing to react to any activity which requires thinking in physics, as well as in science, due to their skills and competencies from previous years of study.

The sample size for this study comprised A-level students who study physics as a major subject, specifically in PCB combination from Kicukiro and Kayonza districts. A total number of 148 students were sampled (Table 2). Purposive sampling was considered while selecting the districts, and the day schools and boarding schools were randomly selected. The whole class was used to address the bias issue in the selection of students (Fraenkel et al., 2012). The two schools (i.e. one day and one boarding school) were selected in each district which led researchers to collect data from four schools.

Table 2: Sample size of participants administered in the study

Variable		Number of students	Percentage
Gender	Male	80	54.1
	Female	68	45.9
	Total	148	100.0
School Location	Urban	96	64.9
	Rural	52	35.1
	Total	148	100.0

Data Analysis of the Findings

Microsoft Office Excel and SPSS version 21.0 allow data entry and analysis respectively. Frequency, percentage, and central tendency measures were computed to investigate research question one, while a *t*-test and a 0.05 significance level were used to answer research question two. Thematic analysis was used to analyze the qualitative data in which different categories were drawn from the participant's responses.

3. Findings

The findings of this study are presented using descriptive statistics and inductive reasoning. In addition, the results are compared to other findings with related interests. Before running any descriptive and inferential statistics about NOS aspects versus different variables, the similarity and consistency of variance were calculated and checked through Levene's test. The findings noted a similarity between variables. Sig. value was found to be $p > 0.05$ as shown in Table 3.

The findings also indicated that senior secondary physics students in Rwanda hold strong misconceptions in five NOS aspects as shown in Table 4. However, the scientific method is highly ranked as an aspect that is very difficult to understand among all seven targeted NOS aspects.

Table 3. The variability of scores between variances

NOS aspect	Levene's test for equality of variances	
	Gender Sig.value	School location Sig.value
Tentative nature of scientific knowledge	0.136	0.999
Empirical nature of science	0.685	0.170
Observation and inferences	0.779	0.612
Relationship between scientific laws and theories	0.764	0.398
Creativity and imagination in science	0.293	0.675
Social and cultural contexts in science	0.546	0.794
Scientific methods in science	0.724	0.849

Physics Students' Views on Different NOS Aspects

To investigate the physics students' views on targeted NOS aspects, frequency (*f*), percentage (%), mean (*M*) and standard deviation (*SD*) were generated; this is shown in Table 4.

Table 4 indicates that the physics students hold naïve views on all seven targeted aspects of NOS. The results revealed that most of the respondents (117 students) disagreed (combining 'Strongly Disagree' and 'Disagree') with the tentative nature of scientific knowledge (79.1%, M=1.96, SD=0.058), where M is the mean of responses of students for all items related to an aspect of NOS on Likert scale. A total of 115 students (77.7%, M=1.93, SD=1.082) disagreed on the empirical nature of science.

On the aspect of 'observation and inferences', 102 students (68.9%, M=2.24, SD=1.149) disagreed. A further 116 students (78.4%, M=1.93, SD=0.967) disagreed on the aspect of the 'relationship between scientific laws and theories'. Above half of the students were found with naïve views on 'creativity and imagination in science', of which 87 students disagreed (58.8%, M=2.46, SD=1.293). A large number (110) of students (74.3%, M=2.01, SD=1.024) disagreed on the influence of 'social and cultural contexts' in developing science. 'Scientific methods in science' was identified as a NOS aspect among other targeted NOS aspects in which a large number (120) of students (81.8%, M=1.83, SD=0.991) were found with strong misconceptions.

As indicated in Table 4, a slightly high mean (2.46) and standard deviation (1.293) were noted in 'creativity and imagination in the science' aspect compared to other NOS aspects. This is because a considerable number of participants showed informed views of some items under this aspect. For example, this study indicates a considerable number (48) of respondents (32.4%, M = 2.70, SD = 1.375) who hold informed views on an item that states 'scientists use their imagination and creativity only when they design experiments'.

Therefore, this study noted a good number of physics students who demonstrated an understanding of some items of creativity and imagination aspect versus other targeted NOS aspects in this study.

Table 4. Physics students' views on emphasized aspects of NOS

NOS aspect	**Strongly Disagree and Disagree**	**Neutral**	**Strongly Agree and Agree**	**Mean *M***	***SD***
	f **(%)**	***f*** **(%)**	***f*** **(%)**		
Tentative nature of scientific knowledge	117(79.1)	15(10.1)	16(10.8)	1.96	1.058
Empirical nature of science	115(77.7)	14(9.5)	19(12.8)	1.93	1.082
Observation and inferences	102(68.9)	20(13.5)	26(17.6)	2.24	1.149
Relationship between scientific laws and theories	116(78.4)	17(11.5)	15(10.1)	1.93	0.967

Creativity and imagination in science	87(58.8)	22(14.9)	39(26.3)	2.46	1.293
Social and cultural contexts in science	110(74.3)	21(14.2)	17(11.5)	2.01	1.024
Scientific methods in science	121(81.8)	14(9.4)	13(8.8)	1.83	0.991

The findings in Table 4 show that the senior secondary physics students in selected four schools hold inadequate views in all targeted NOS aspects. Particularly, they have strong misconceptions in five NOS aspects, namely 'scientific methods', 'tentative nature of science', 'the relationship between scientific laws and theories', 'empirical nature of science', and 'social and cultural contexts in science'.

Strong misconceptions in above mentioned five aspects are indicated by a big number of students who hold uninformed views on some items from those aspects. For instance, on the 'tentative nature of science', most of the students (85.9%) though that absolute truth about scientific knowledge can be reached with the help of technological development. The same number of students (85.9%) agreed with an item under the aspect of the scientific method which stated that 'when scientists use the scientific method correctly, their results are true and accurate'.

Looking at 'the relationship between scientific laws and theories', 81.8% of students viewed that 'scientific theories have to be proven several times to become scientific laws'. The item 'the acceptance of scientific theory entirely depends on experimental evidence', under empirical nature of science was identified with the highest percentage (90.6%) of students with strong misconceptions compared to the other items used in the data collection.

Understanding of NOS Aspects by Gender

The understanding of NOS aspects by male and female physics students was analyzed using central tendency measures such as means and standard deviation, in addition to frequency and percentage. The *t*-test was also used for equality of means to determine whether there is no influence of gender on the understanding of targeted NOS aspects in this study. Table 5 indicates the frequency and percentages of physics students concerning their gender who hold naïve and informed views of targeted NOS aspects, while Table 6 compares the mean to check whether the views on NOS are influenced by students' gender.

Table 5. Understanding of physics students' views of emphasized aspects of NOS by gender

NOS Aspect	Strongly Disagree and Disagree		Neutral		Strongly Agree and Agree	
	Male N = 80	Female N = 68	Male N = 80	Female N = 68	Male N = 80	Female N = 68
	f (%)	*f* (%)	*f* (%)	*f* (%)	*f* (%)	*f* (%)
Tentative nature of scientific knowledge	64(80.0)	50(73.5)	6(7.5)	12(17.7)	10(12.5)	6(8.8)
Empirical nature of science	63(78.7)	52(76.5)	5(6.3)	9(13.2)	12 (15.0)	7(10.3)
Observation and inferences	55(68.8)	47(69.1)	9 (11.2)	11(16.2)	16 (20.0)	10(14.7)
Relationship between scientific laws and theories	65(81.2)	52(76.5)	8(10.0)	9(13.2)	7(8.8)	7(10.3)
Creativity and imagination in science	46(57.5)	42(61.8)	12(15.0)	10(14.7)	22(27.5)	16(23.5)
Social and cultural contexts in science	60(75.0)	55(80.2)	9(11.2)	12(17.7)	11(13.8)	6(8.8)
Scientific methods in science	67(83.7)	54(79.4)	7(8.8)	7(10.3)	6(7.5)	7(10.3)

Examining the frequency (*f*) and percentages of students in Table 5, the findings indicate that the understanding of NOS aspects by students' gender is not significantly different. The findings also reveal that a large number of both males (55% and above) and females (60% and above) hold an inadequate understanding of all targeted NOS aspects as shown in Table 5.

The findings in Table 6 indicate that there is no considerable difference in physics students' views on NOS concerning gender as the *p*-value is greater than 0.05. Table 6 indicates the comparison of the central tendency measures, such as mean and standard deviation of the understanding of NOS aspects by students' gender.

Table 6. Comparison of the students' understanding of NOS aspects by gender

NOS aspect	Students' gender		*t*-test for equality of means		
	Male	Female			
	N = 80	N = 68			
	Mean *M*(*SD*)	Mean *M*(*SD*)	*t*-value	Df	Sig. *p*
Tentative nature of scientific knowledge	1.90(1.116)	2.04(0.965)	-1.544	146	0.125
Empirical nature of science	1.90(1.092)	1.97(1.057)	-0.724	146	0.470
Observation and inferences	2.28(1.198)	2.21(1.076)	0.340	146	0.734
Relationship between scientific laws and theories	1.86(0.922)	2.02(0.994)	-1.866	146	0.064
Creativity and imagination in science	2.50(1.341)	2.42(1.234)	0.714	146	0.477

Social and cultural contexts in science	2.00(1.056)	2.01(0.991)	-0.026	146	0.979
Scientific methods in science	1.78(0.987)	1.89(0.993)	-1.361	146	0.176

As shown in Table 6, a *t*-test was run to compare students' views on the 'tentative nature of science' for males and females. The findings of the analysis show that there is no considerable difference in understanding between males (*M* = 1.90, *SD* = 1.116) and females [*M* = 2.04, *SD*=0.965; *t* (146) = -1.544, *p*= 0.125]. Similar understandings between males (*M* = 2.28, *SD* = 1.198) and females [*M* = 2.21, *SD* = 1.076; *t* (146) = 0.340, *p* = 0.734] were identified on the aspect of 'observation and inferences'. It was also noted that the understanding of 'the relationship between scientific laws and theories' is not significantly different between males (*M* = 1.86, *SD* = 0.922) and females [*M* = 2.02, *SD* = 0.994; *t* (146) = -1.866, p = 0.064]. There is no significant difference in understanding of 'creativity and imagination in science' between males (*M* = 2.50, *SD* = 1.341) and females [*M* = 2.42, *SD* = 1.234; *t* (146) = 0.714, *p* = 0.477].

There is no significant difference in the understanding of 'social and cultural contexts in science' between males (*M* = 2.00, *SD* = 1.056) and females [*M* = 2.01, *SD* = 0.991; *t* (146) = -0.026, *p* = 0.979] and, like other targeted NOS aspects in this study, 'scientific methods in science' also did not mark the significant difference in understanding between males (*M* = 1.78, *SD* = 0.987) and females [*M* = 1.89, *SD* = 0.993; *t* (146) = -1.361, *p* = 0.176].

The overall effect of gender on NOS understanding among students is not significantly different, but examining each item used in the data collection in-depth, a slight difference in NOS understanding versus gender was noted. For instance, the findings showed that males (81.2%) hold an inadequate understanding of the item 'Some of the scientific theories produced by scientists changed after their development' compared to the females (66.1%). On the item 'Scientific theories may be completely replaced by new theories in the light of new evidence', the study reported that males (80.0%) hold significantly more naïve views than their female counterparts (66.1%).

Additionally, this study reveals that females hold inadequate NOS understanding of observations and inferences and creativity and imagination. For example, on the item 'scientists may make different interpretations based on the same observable phenomenon', it was noted that females (79.4%) hold significantly more naïve views compared to males (66.2%). Furthermore, an item that stated that 'when scientists use the scientific method correctly, their results are true and accurate' was identified as an item under the scientific method in which both males (86.2%) and females (85.2%) students hold strong misconceptions.

Understanding of NOS Aspects by School Location

The schools' location indicated in this study refers to urban schools and rural schools. The results indicated that the schools' location does not affect the understanding of NOS aspects as shown in Table 7.

Table 7. Understanding of NOS aspects by school location

NOS Aspect	School Location		*t*-test for Equality of Means		
	Urban	Rural			
	N = 81	N = 67			
	Mean *M(SD)*	Mean *M(SD)*	*t*-value	Df	Sig. *p*
Tentative nature of scientific knowledge	1.97(1.073)	1.96(1.044)	-0.060	146	0.952
Empirical nature	1.95(1.112)	1.91(1.042)	0.346	146	0.730
Observation and inferences	2.20(1.112)	2.29(1.185)	0.062	146	0.951
Relationship between scientific laws and theories	1.91(0.945)	1.96(0.980)	-0.474	146	0.636
Creativity and imagination in science	2.52(1.353)	2.39(1.221)	1.075	146	0.281
Social and cultural contexts in science	1.99(1.038)	2.03(1.011)	-0.475	146	0.635
Scientific methods in science	1.90(1.027)	1.75(0.940)	1.809	146	0.073

According to Table 7, the findings of the analysis show that there was no considerable difference in understanding of 'the tentative nature of science' for urban (M = 1.97, SD = 1.073) and rural [M = 1.96, SD=1.044; t (146) = -0.060, p= 0.952] school students. There is no significant difference in understanding on 'observation and inferences' for urban (M = 2.20, SD = 1.112) and rural [M = 2.29, SD = 1.185; t (146) = 0.062, p = 0.951] school students. It was also noted that the understanding on 'relationship between scientific laws and theories' was not significantly different between urban (M = 1.91, SD = 0.945) and rural [M = 1.96, SD = 0.980; t (146) = -0.474, p = 0.636] school students. There is no significant difference in understanding of 'creativity and imagination in science' between urban (M = 2.52, SD = 1.353) and rural [M = 2.39, SD = 1.221; t (146) = 1.075, p = 0.281] students. There is no significant difference in understanding of 'social and cultural contexts in science' between urban (M = 1.99, SD = 1.038) and rural [M = 2.03, SD = 1.011; t (146) = -0.475, p = 0.635] and like other targeted NOS aspects in this study, 'scientific methods in science' also did not mark the significant difference in understanding between urban (M = 1.90, SD = 1.027) and rural [M = 1.75, SD = 0.940; t (146) = 1.809, p = 0.073].

4. Discussion of the Findings

The findings from close-ended questions indicate that the senior secondary physics students in Rwanda hold an inadequate understanding of all seven targeted aspects of NOS. Particularly, strong misconceptions were identified in five NOS aspects, namely 'scientific methods', 'tentative nature of science', 'the relationship between scientific laws and theories', 'empirical nature of science', and 'social and cultural contexts in science'. A large number of students who hold uninformed views on these aspects was noted.

In addition to the students' answers to close-ended questions as shown in Table 4, the misunderstanding about targeted NOS aspects among students was also clearly seen in students' answers to open-ended questions which accompanied close-ended questions on each NOS aspect. For example, many students showed inadequate views on the 'tentative nature of science' as described.

One student coded with S014 wrote that "*It may be changed when the scientific methods are used incorrectly and may not be changed when scientists use accurate experimentation which leads to the true and permanent scientific theories*". A student with a code of S034 said "*I think, they should not be changed but there should be some innovation but not replacing or removing old scientific theories by the new ones*". Another student with a code of S056 mentioned that "*for example, the atomic theory will not change because it has been proved as a correct theory. So, if it is correct, the theory has to remain the same so that it can be applied in our daily life*".

A student with a code of S062 said that scientific theory may not be changed because it is difficult to see scientists who may change their laws and theories. A student with code S138 also confirmed an inadequate understanding of the tentative nature by saying that "*scientific theory does not change over time because scientists had provided all evidence necessary required to explain it well*".

Open-ended responses from the participants confirm the quantitative findings in which many respondents hold strong misconceptions about 'the relationship between scientific theories and laws'. For instance, a student with a code of S005 answered that "*scientific theories are proposed statements which are not fully accepted universally while scientific laws are fully accepted worldwide*". A participant with a code S067 said that "*scientific theories cannot change but scientific laws may change*". A student with a code S115 justified why scientific theories may change by saying that Thomson's atomic theory was opposed by Rutherford, but the same student (S115) urged that scientific laws cannot be changed because they are permanent inventions. Another student with a code of S127 showed a misconception about the relation between scientific laws and theories while confirming that 'scientific theories have to be proved several times to become scientific laws'.

The results converge with that of a study by Yoon et al. (2014) and that of Yadav and Shrivastava (2007), where their studies reported that the most of respondents held an insufficient knowledge of the NOS. The findings also agree with other studies which found that students hold inadequate views on the NOS (Dogan & Abd–El–Khalick, 2008; Yenice & Saydam, 2010). Similar results were also noted in a study by Herman et al. (2022), in which many participants were found with a strong misconception about the scientific method. For instance, the participants opined that science must follow a single set method. The findings of this study are aligned with that of Yacoubian (2021) in which three of four interviewed participants showed inadequate understanding of the tentative aspect of NOS and the relationship between laws and theories. In this study, one student urged that facts and laws will not change and added that laws are unchangeable because they have been proven through different scientific approaches (Yacoubian, 2021).

Several research studies reported that gender may influence conceptual understanding and students' performance in science subjects (Lin et al., 2016). For instance, in a study by Acar et al. (2015), females scored better than their counterparts in conceptual knowledge physics test. In addition to this, some studies carried out in Rwanda also showed that gender and school location affect students' perception and performance of scientific subjects (Bizimana et al., 2022; Mukagihana et al., 2021). In this regard, the focus is on the investigation of the influence of these factors for further recommendations to improve smooth learning of NOS aspects in the Rwandan context.

Subsequently, the findings of this study show that students' gender and their understanding of NOS are not connected. Similar findings were reported in several research studies. For example, Acar et al. (2015), found that there was no difference between "males and females in scientific reasoning and NOS understanding among physics students". Similar findings were also reported in studies by Dogan and Abd–El–Khalick (2008) and Tsybulsky et al. (2017), where these researchers found that NOS understanding among students was not influenced by their gender.

Furthermore, the results of this study also indicated that schools' location does not influence the understanding of the NOS aspects. These results are consistent with that of Yenice and Saydam (2010) and Yoon et al. (2014) who reported that the student's residence does not affect the understanding of NOS aspects. The findings in a study by Ntibi and Edoho (2017) also lead to the conclusion that this is no effect of school location on NOS understanding among students.

However, other researchers found that these factors may influence the conceptual understanding of nature of scientific knowledge (Kiliç et al., 2005). Therefore, this study recommends further investigation of these factors for different grades of students.

5. Conclusion and Recommendations

The major goal of this study is to fill the gap in the literature, in the context of Rwanda, on views of NOS among secondary school physics students. The study may also help science education researchers in the region to identify or develop effective interventions to improve NOS understanding among Rwandan or East African community students.

This study revealed that Rwandan physics students show misconceptions about all targeted NOS aspects. The study also indicated that students have strongly held naïve views in five aspects ('scientific methods'; 'tentative nature of science'; 'scientific laws and theories'; 'empirical nature of science'; and 'social and cultural contexts of science') compared to the remaining NOS aspects considered in this study. For instance, most participants believed that accurate experimentation leads to permanent scientific theories. Many students opined about true and accurate results "*when scientists use the scientific method correctly*". Most of the students in this study said that "*scientists follow a single universal step-by-step scientific method*" to produce knowledge. In addition to this, many students in this study opined that scientific theories have to be proven several times to become scientific laws. The student's gender and school location were identified as factors that do not influence the understanding of NOS. The results showed that both male and female students hold similar naïve views towards all targeted NOS. The study also indicated that there is no significant influence of either boarding or day schools. The results also indicated that both schools from rural and urban areas share similar naïve views on all targeted NOS aspects.

Strongly held naïve views among most Rwandan secondary school students on several aspects of NOS indicate some serious problems in teaching/learning science. There may be several reasons for it. It seems that there is a low representation of NOS in the physics curriculum and textbooks for secondary school students, and/or teachers might not be using appropriate methods to teach aspects of NOS. Secondary school teachers might also be having naïve conceptions of NOS, which may be due to poor pre-service training of physics teachers on aspects of NOS. These plausible reasons need to be further investigated.

The present study did not investigate the reasons why Rwandan students have naïve conceptions of different aspects of NOS. Further studies are needed to check to which extent various interventions may affect the students' views on NOS. It is very important for science educators in the region, particularly in Rwanda, to review science teaching materials vis-à-vis the integration of NOS aspects.

6. Acknowledgements

The authors would like to send warm thanks to the ACEITLMS for financial support. Thanks are due to Kayonza and Kicukiro Education Officers for providing permission to conduct research in both districts.

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