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Comparison Test Between Amrita Virtual Lab and Real Spectrometer on Refractive Index Using Blended Laboratory

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Abstract.
Education in the 21st century is an era where learning is unconventional. Interactive learning in the 21st century can be done by conducting virtual or real laboratory activities, even by combining the two in one activity at once. Various innovations in virtual laboratories have spread to optical materials, especially refraction by using a virtual spectrometer. Conceptually, the refractive index is a measure of the bending ray of a light beam as it passes from one medium to another. The refractive index is given by measurement between the refractive index of air, the angle of the prism, and the angle of minimum deviation. The angle of the prism and the angle of minimum deviation can be measured with a spectrometer. The spectrometer is a scientific instrument used to separate and measure the spectral components of physical phenomena and can separate white light and measure individual narrow color bands. Other than an on-hand spectrometer, other tools that we can use to measure the angle of minimum deviation are by using a virtual spectrometer provided by several virtual labs. The study aimed to compare the result of refractive index between on on-hand spectrometer and a virtual lab. Here we report our study on spectrometer whether the virtual lab experiment yields the same results as the real lab. We compare both results of experimental data using data and graph analytics. The results of the study show that the difference in the index of refraction measured between the virtual lab and the real lab is about 0.2%. This shows that there is no significant difference between virtual lab and real lab.

Keywords: amrita virtual lab, real spectrometer, refractive index, blended laboratory

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1. INTRODUCTION

The revolution of the 21st century has a global and widespread impact on all aspects of human life, including education. This is characterized by an increase in various technologies until they are adopted in education. The development of technology leads to innovation in interactive learning through virtual laboratory (virtual lab). Virtual lab is a series of virtual experiment laboratories that have been designed and programmed

[1]. Using a virtual lab has many advantages, including: (a) Perform time-consuming experiments in less time; (b) perform dangerous experiments in a safe environment; (c) reproduce events that are difficult to observe in physical laboratories; and (d) lower cost instead of expensive laboratories [2, 3]. One of the virtual labs that offers several virtual measuring instrument is Amrita Lab.

Amrita Lab is an interactive virtual lab that provides several simulation and virtual experiment laboratories that made by Amrita University's Center for Research in Advanced Technologies for Education [4]. This virtual lab provided some virtual measuring devices that can be used in physics practicum. One of them is a spectrometer. Spectrometer can be used for measuring refractive index, Cauchy's constant, and learning about light's characteristic in general.

Light has several properties, one of which can be refracted as it passes through two different mediums [5, 6]. We often find natural phenomena associated with it in our daily lives. As an example, when we put a pencil on a glass of water, it looks like it's broken from the side of the glass. This phenomenon is known as refraction or deflection.

Refraction is the bending of a wave as it enters media of different velocities. The refraction of light as it travels from a high-speed medium to a low-speed medium bends the light ray toward the normal boundary between the two media. The magnitude of the bend depends on the index of refraction of the two media and is quantitatively described by Snell's law [7].

The refractive index is a measure of the bending ray of a light beam as it passes from one medium to another [8, 9]. The refractive index of a material medium is an important optical parameter since it exhibits the optical properties of the material [10]. Its value is often needed to interpret different types of spectroscopic data. The refractive index tells the behavior of light in different materials. The index is used to determine the focusing power of material like lenses [11, 12]. It is also used to measure the amount of particles that are dissolved in a solution.

If a light ray passes through an isotropic solid material in the form of a prism or a crystal, the refractive index n_2 of the prism is given by [[10]],

$$n_2 = \frac{n_1 \sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)} (1)$$

n_1 is generally the refractive index of air, A is the angle of the prism and D is the angle of minimum deviation. The minimum deflection angle D occurs only when $\alpha_1 = \alpha_2$. That is, the angle of incident α_1 is equals to the angle α_2 at which the light ray exits the

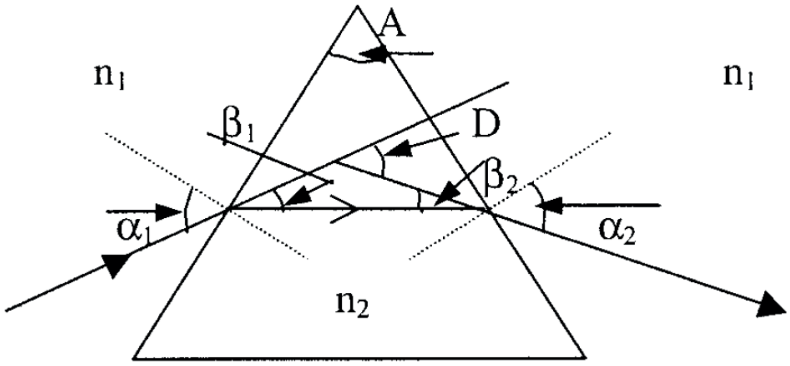

Figure 1: Refraction Through a Prism of the Refractive Index n_2 [10].

prism. The refraction angle A of the prism in this state is $A = \beta_1 + \beta_2$. The angle of the prism and the angle of minimum deviation can be measured with a spectrometer [10].

Spectrometer is a scientific instrument used to separate and measure the spectral components of physical phenomena. A spectrometer is a broad term often used to describe a device that measures a continuous variable of the phenomenon in which spectral components are somehow mixed. In visible light, the spectrometer can separate white light and measure individual narrow color bands called spectra [13]. Other than on hand spectrometer, other tools that we can use to measuring angle of minimum deviation is by using virtual spectrometer that provided by Amrita Lab. This work report a study of prism's refractive index generated by on hand spectrometer compare to the virtual spectrometer that supported by Amrita Lab.

2. RESEARCH METHOD

This study was carried out using an experimental method involving laboratory activity on the spectrometer and virtually using Amrita Lab (http://ov-au.vlabs.ac.in/optics/Cauchys_Constant/experiment.html). Experimental method is used to search the causal effect between the the independent and dependent variables that used in this research [14, 15]. The data obtained is manually analyzed quantitatively and qualitatively. The research process is shown in Figure 2.

The experiment was carried out to determine the measurement of refractive index of prism. We measured each position of both polychromatic and monochromatic color with vernier caliper that attached on spectrometer in degree scale. Sum of color that measured are red, orange, yellow, green, blue, violet, and white. The experiment was run 5 times to obtain the correct accuracy and uncertainty values. The real laboratory

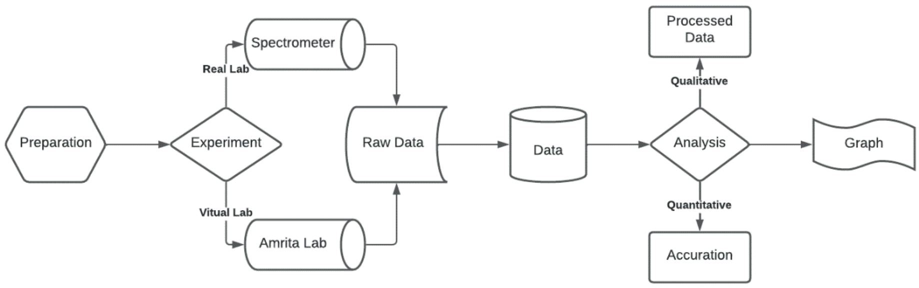

Figure 2: Research flowchart.

experiment was conducted to obtain comparative data. The tools and procedures are adapted to the experiments performed in the virtual lab, so the data that we achieved is same as the virtual experiments.

3. RESULTS AND DISCUSSION

Research in the real lab was carried out in the same series of experiments as in the virtual lab to maintain the similarity and validity of the corresponding data. Also, no high error score was obtained. Spectrometer used to measure each color angle value to determine its refractive index. Table 1 shows the refractive index values for each color that passes through the prism.

TABLE 1: Real lab data on spectrometer.

Color	**Wavelength (1/$\square^2$. 10^{-6} nm)**	**Refractive Index (n)**					**Mean of Refractive Index**
		1st	**2nd**	**3rd**	**4th**	**5th**	
Red	2.131	1.080	1.079	1.084	1.085	1.085	1.083
Orange	2.732	1.085	1.089	1.089	1.090	1.092	1.089
Yellow	2.972	1.090	1.092	1.095	1.093	1.095	1.093
Green	3.526	1.097	1.099	1.10	1.10	1.101	1.099
Blue	4.479	1.101	1.105	1.103	1.105	1.107	1.104
Violet	5.806	1.107	1.108	1.108	1.110	1.112	1.109

Table 1 shows that there is an increase in the average value of refractive index depending on the wavelength of various color. Thormählen [[16]] in his research shows linear results with changes of the wavelength. It means as the wavelength increases, it gives a constant increase in the refractive index value for each different color. The value of the increase in the refractive index to wavelength can be seen in Figure 3.

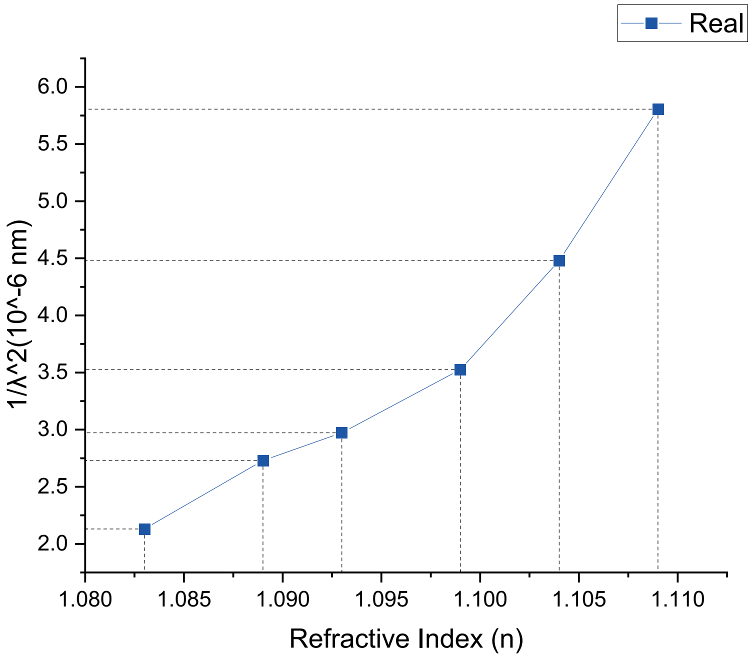

Figure 3: Effect of wavelength on refractive index in real lab.

The increase in the graph is quite significant from the first wavelength through the last. This graph is also shown a linear result with research that conducted by Singh [10]. By the increase of wavelength, the refractive index was also increased the Standard deviation and error values obtained from each colors refractive index can be seen in Table 2.

Table 2: Standard deviation and error values.

Color	**Wavelength (1/λ^2 . 10^{-6} nm)**	**Standard Deviation**	**Error Values**
Red	2.131	0.0029	0.0013
Orange	2.732	0.0025	0.0011
Yellow	2.972	0.0021	0.0009
Green	3.526	0.0015	0.0007
Blue	4.479	0.0023	0.0010
Violet	5.806	0.0020	0.0009

Virtual lab experiment carried out on Amrita Lab using a virtual spectrometer. The variables used in the virtual experiment were adjusted to the real lab experiment to create compatible data with validity. Table 3 shows the virtual laboratory experimental data.

TABLE 3: Virtual lab data on amrita lab.

Color	Wavelength ($1/\lambda^2$. 10^{-6} nm)	Refractive Index (n)					Mean of Refractive Index
		1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	
Red	2.131	1.093	1.093	1.093	1.093	1.093	1.093
Orange	2.732	1.094	1.094	1.094	1.094	1.094	1.094
Yellow	2.972	1.099	1.099	1.099	1.099	1.099	1.099
Green	3.526	1.101	1.101	1.101	1.101	1.101	1.101
Blue	4.479	1.108	1.108	1.108	1.108	1.108	1.108
Violet	5.806	1.117	1.117	1.117	1.117	1.117	1.117

Table 3 shows that there is an increase over the refractive index depending on the wavelength of color. As the wavelength of the color increases, the refractive index will increase as well. In his work, Schiebener [[17]] shows a linear result that the refractive index value for each color increases steadily with increasing wavelength. There are no changes that vary in the use of the virtual lab, because virtual Lab is a lab activity that has been programmed using measurements made by a real lab[[18]]. Figure 4 shows the value of the increase in the refractive index with wavelength.

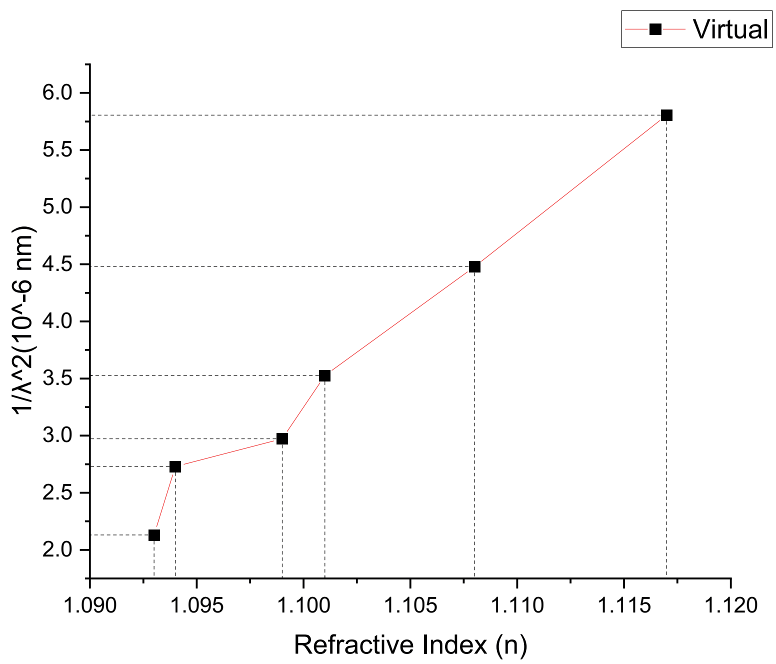

Figure 4: Effect of wavelength on refractive index in virtual lab.

The constant change in refractive index indicates that there is an effect of color wavelength on the color refractive index through prism. The graph results obtained in

Figure 4 are in line with the research conducted by Thormählen [[16]] which shows linear results with changes of the wavelength. Another similar result comes from a study by Mukhlis [[19]], showing that the wavelength of the color passing through the prism affects its index of refraction. Dalgarno [[20]] in his research explained that the consistency of the results using the virtual laboratory is due to a set of results designed to remain unchanged unless new variables are added in further development. Sugiana [[21]] state that the results of using a virtual lab will be the same results without any changes in the data. This allows virtual labs to help student to understand the basic concepts. There is a difference between the measurement results of the actual laboratory and the virtual laboratory. Figure 5 shows a comparison between a real lab and a virtual lab.

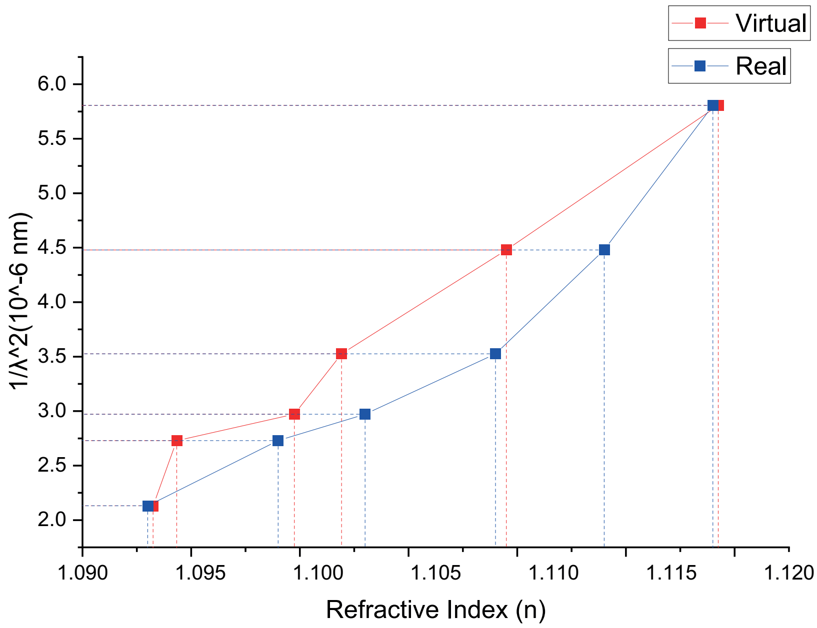

Figure 5: Comparison of color refractive index between real lab and virtual lab.

Figure 5 shows the resulting comparisons are only slightly different and not too significant. This differences occur due to human error when conducting experiments and also inadequate tool calibration. The result of the percentage comparison between real lab and virtual lab can be seen in Table 4 that calculated using equation 2.

$$Difference = \frac{Real Lab - Virtual Lab}{Real Lab} \times 100 (2)$$

In this comparison, it can be seen that the comparison value between real lab and virtual lab produces an insignificant difference which is still at the <1% level. Therefore, the use of a spectrometer with Amrita-based virtual lab does not make a big difference. Virtual lab is an integrated laboratory activity tool designed and determined based on the value of real laboratory experiments[22]. In addition, the virtual laboratory results

TABLE 4: Comparison between real lab and virtual lab.

Color	Wavelength ($1/\lambda^2$. 10^{-6} nm)	Difference (%)
Red	2.131	0.938
Orange	2.732	0.496
Yellow	2.972	0.533
Green	3.526	0.159
Blue	4.479	0.338
Violet	5.806	0.696

reach almost 0%, with the measurement accuracy in the laboratory being high and low acquisition error values.

4. CONCLUSION

In the comparison experiment of Amrita Virtual Lab and real spectrometer, the comparison value is not too significant and not much different between the two. This difference is found in the values of 0.938% for red refractive index, 0.496% for orange refractive index, 0.533% for yellow refractive index, 0.159% for green refractive index, 0.338% for blue refractive index and 0.696% for violet refractive index through a prism. The differences caused by human errors that occurred during the study. Based on the results of this study, the comparison between real and virtual labs is about the same. It shown that both real lab and virtual lab can be used for learning activity. However, in the real lab, the results found will always vary depend on the state of the fields compared to a systematically programmed virtual lab. Therefore, this virtual lab is considered suitable for blended laboratory activity.

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