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Exploring the Effects of Video-based Multimedia instructional strategies on students' performance in Astrophysics in Rwandan Secondary Schools

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HIGHLIGHTS

- Learners taught astrophysics using Video-Based Methodology strategies performed much better than learners taught astrophysics using normal strategies
- Girls' performance is marginally higher than boys' performance when taught astrophysics using Video-Based Methodology
- Urban students had considerably higher performance than their rural counterparts when taught astrophysics using Video-Based Multimedia

ABSTRACT

Now, more than ever before, innovative teaching methodology in STEM education has been a matter of concern. Previous research abounds settling the importance of technology-based methodology in STEM education. This study seeks to explore the effects of video-based multimedia (VBM) on students' performance in astrophysics in certain scientific schools in Rwanda. The current study presents the findings of a quasi-experiment non-equivalent control group carried out from eight scientific schools where 294 students in science combination with physics as a major subject were purposively selected. Pre-test and post-test were used to collect data using an astrophysics achievement test (AAT) with a Cornbanch Alpha of 0.87. The results of the study showed the widespread effects of VBM in enhancing the students' performance in astrophysics. The results show that also girls did marginally well compared to boys, however, special attention is needed in rural-based schools. The findings of this study offer a suggestion on the essential to integrate VBM in teaching physics.

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1. Introduction

Now, more than ever before, the quality and equity of the education system are the baselines of effective outcomes in society's well-being and welfare (Bram, Fleming, & Sheils, 2023; Institute of Education Sciences[IES], 2012). Therefore, the endeavor to enhance the quality and equity of education can help shape the future of any society worldwide and help to produce the kind of citizens the country needs (REB, 2015). The ambition to develop a knowledge-based society and global competition led to the promotion of science, technology, engineering, and mathematics (STEM) education (Marcus et al., 2023; Vali, 2013). Physics is one of the fundamental scientific disciplines and deals with the understanding of how the universe behaves (Halliday et al., 2013). Physics deals with matters, energy, and force; its vital constituents, its movement in time and space, and behavior (Rovelli, 2016).

Physics tenants a noticeable position in STEM education because of its potential discoveries that contribute significantly to the global socio-economic transformation (David, 2015; Guan et al., 2020). Physics led to the improvement of innovative technologies in all areas of creativity and is useful to mankind (Ellermeijer & Tran, 2019). For instance, advancements in astrophysics and astronomy contribute to developments in medicine, industry, defense, environmental monitoring, and consumer products (Tyson, 2017). Advancements in mechanics and thermodynamics contribute significantly to industrialization development (Alvarado, 2012; Weinberger, 2013). Improvement and understanding of electromagnetic led to the development of new machines used in modern medicine such as magnetic resonance imaging (MRI) (Gossuin et al., 2010). Moreover, the bid for physics knowledge and values is obvious in many modern innovations such as nuclear-powered materials (Kristensen, 2016), electric appliances (Pandey, 2020), and computers (Wolf, 2016).

Regardless of the gigantic input of physics to personal, national, and international development, the performance of learners in physics has not been as worthy as expected over the years. The poor performance in physics is not new, neither is it unique to the Rwandan context (Lacambra, 2016; Mbonyiryivuze et al., 2021; Ndihokubwayo et al., 2020). This poor performance affects negatively the future of learners who need to continue their studies in physics-related courses. The poor performance of physics also affects the needs of the learners, society, and the labor market (Mushinzimana & Sinaruguliye, 2016).

Several reasons have been attributed to the students' poor performance in STEM education in general and physics in particular. The most cited factor that is associated with learners' poor performance in physics is students' attitude (Mbonyiryivuze et al., 2021) and poor methodology used (Ndihokubwayo et al., 2020). Recent study reported that the methodology used in teaching STEM subjects is of great importance in making the learning of science easy and enjoyable for students (Arztmann et al., 2023; Byusa et al., 2020; Mukuka et al., 2019; Ndihokubwayo et al., 2020; Serrano & Rodríguez, 2020; Zendler et al., 2018). Similarly, recent studies reported that the methodology used by STEM teachers does not contribute to the learners' knowledge construction which in turn leads to the learners' poor performance (Byusa, 2021; Kuna & Prasad, 2019; MolokoMphale & Mhlauli, 2014). Moreover, teachers are judged on the learners' results in the national examination (Meissel et al., 2017). This pushes teachers to use traditional methods dominated by lecturing, taking notes, and memorization which deprives learners' opportunity to get engaged in knowledge construction (Mukuka et al., 2019).

Most teachers have a tendency to teach their learners by means of the methods through which they are taught. Conversely, the traditional teaching strategies are not appropriate for the 21^{st} world of fast-paced knowledge growth, technology-led, and petition for competence century (REB, 2015). In line with the foregoing, researchers have advocated for the revision of instructional methods to teach STEM subjects (Mukuka et al., 2019). Some wished-for teaching approaches that have arisen through research and acknowledged extensive success in STEM education include the integration of multimedia in teaching and learning (Ndihokubwayo et al., 2020). The introduction of multimedia in education requests a widespread adjustment and novel thinking with respect to instructional methods in teaching, learning, and evaluation (Herliantari et al., 2019; Jajuri et al., 2019)

Multimedia-based instruction results from the practice of technology in education (Mayer, 2014). Within multimedia-based methodology, students are expected to increase the cooperative and peer, upsurge development in the fast-paced scientific and technologically global, and prepare learners with lively skills, worth, value, and knowledge essential for the human capital in 21^{st} century (Casselman et al., 2021; Mayer, 2020). The selection of an appropriate multimedia teaching tool to incorporate into physics education is enormously didactic and necessitates an assessment process (Lindner et al., 2020). The benefits of multimedia on students' academic performance, retention, and attitude toward physics depend on multiple factors including the design methods the teacher chooses to use in a given topic (Ndihokubwayo et al., 2020; Tugirinshuti et al., 2020).

Moreover, the COVID-19 pandemic break justifies the need to incorporate technology, such as video-based multimedia (VBM) in education. Since the first case of Covid-19 in Wuhan, China in December 2019, the pandemic has spread vigorously globally, and become a global pandemic (World Health Organization [WHO], 2020). Therefore, many governments have initiated several policies to battle the pandemic and to decrease the spreading of Covid-19 (Mukuka et al., 2021; UNESCO, 2020; WHO, 2021). Suspending school activities was one of the measures taken in many countries worldwide (Mugiraneza, 2021). The school suspension activities affected the education system in many countries and 84% of the students in the world were impressed (UNICEF, 2020). Nowadays when things are coming back to normalcy, after school reopening, effective measures for short and long-term plans to shape strong education systems are needed. For instance, the government of Rwanda initiated numerous programs in line with a resilient education system (Mineduc, 2020; Mugiraneza, 2021). Among these initiatives, the effective utilization of ICT and improving the use of multimedia in education were among others (Mineduc, 2020; Mugiraneza, 2021). Nurturing e-learning and virtual classes, teachers' training on the effective use of ICT and digital tools for teaching and learning propose, developing remote evaluation, and increasing ICT infrastructure countrywide were among the priorities (Mineduc, 2020; Mugiraneza, 2021).

Apart from teaching strategies, the issue of school location, urban or rural, especially when talking about the incorporation of technology in education, is another variable that could affect learners' outcomes and performance in physics due to the influence that geographical location exerts on STEM education (Saw & Agger, 2021). The difference concerning conceptual understanding in STEM has been a problem for many years when considering the geographical location, rural and urban (Morris et al., 2021). Researchers in different countries reported that urban students perform better than rural (Avery, 2013; Harris & Hodges, 2018; Chen, 2011) either no difference (Alokan & Arijesuyo, 2013) or rural students dominant urban students. Consequently, studies on geographical location in physics education continued to yield inconsistent results and it has been attributed to unequal exposure of urban and rural students to instructions relevant to physics education and integration of multimedia in education.

Gender was another variable that could not be left behind when talking about science education and integrating technology such as VBM in science education1 (Stoet & Geary, 2018). The issue of gender equity and equality has remained a persistent challenge worldwide in STEM education in general (Makarova et al., 2019), and physics education in particular (Dusen & Nissen, 2020). Thus the issue of masculinity and femininity concerning STEM education has received a lot of attention for many years (Acker & Oatley, 1993; Jia et al., 2020; Kahle et al., 2010). Moreover, the literature is plentifully provided with research on the impact of gender on learners' performance in STEM teaching and learning, and has been uncertain over the years and continued to produce inconsistent results (Seyranian et al., 2018). Researchers reported that girls' education is handicapped by access to resources, teaching and school climate, cultural norms and expectations, and poor infrastructure (Wolf et al., 2016).

2. Problem Statement

Literature has showed the benefits of integrating multimedia in STEM education to improve the learning of various concepts of sciences (Herliantari et al., 2019; Ndihokubwayo et al., 2020). However, the uptake of this innovative instructional strategy is low in Rwandan schools and one of the reasons is that the decision to incorporate VBM as an innovative and modern instructional strategy in the Rwandan curriculum was made based on the studies and experience from other countries. Therefore, there is a need to test its effectiveness in Rwandan schools. Moreover, this study noted a gap in previous studies that have not considered gender and school location and yet are issues of concern not only in Rwanda but also elsewhere in Sub-Saharan countries' schools. Thus, the current study seeks to explore the effectiveness of VBM on learning astrophysics together with its effect on gender and school location. The criteria for investigating the effectiveness of VBM on learning astrophysics were subject conceptual understanding and class performance with respect to school location and gender. Henceforth, with reference to the literature review and research problem stated above, this study pursues to test the research hypotheses (RH) at a 0.05 level of significance.

RH1: There is no statistically significant difference in mean achievement scores in astrophysics of learners taught astrophysics using VBM and those taught astrophysics using the teachers' usual teaching strategies

RH2: There is no statistically significant difference in conceptual understanding of astrophysics between urban students and rural students taught using VBM.

RH3: There is no statistically significant difference in conceptual understanding and motivation of astrophysics between boys and girls taught using VBM.

3. Research Methodology

3.1.Research design & Paradigm

A quasi-experimental design with a pretest and posttest for the control and experimental group was used in this study. Based on the positivist world of view (Park et al., 2019), this study uses the quantitative method which assisted us in evaluating the learners' achievement after four weeks of VBM teaching intervention.

3.2.Sampling and Research Participants

This study was conducted among public schools in the Rutsiro and Rubavu districts which are rural and urban settled areas respectively. Eight schools, four from each district were purposively chosen. Two main criteria for selecting schools were: 1) schools that have physics as a major subject in STEM combination and 2) schools that have smart classrooms known as computer laboratories. Among the selected schools, the targeted respondents were senior five students. The reason pushed the researchers to choose that group was to strike a balance since senior five is at the middle class in an advanced level and has been taught some introductory concepts about astrophysics as far as the advanced level curriculum in the Rwandan education system is concerned.

In view of the sampling criteria set above, eight public schools (four from each district) made a total of 294 (168 boys and 126 girls) senior five students sampled for this study. Among the four selected schools in each district, two were randomly allocated to the experimental group, and the other two were assigned to the control group. This made up four schools in the experimental group and four in the control group. Students in the experimental group were taught using VBM while those in the control group were taught using normal teaching methods. The topic area covered in all groups was astrophysics, and the unit covered was stellar distance and radiation.

3.3.Instruments and Validation

For this study, the Astrophysics achievement test (AAT) for pre-test and post-test were used. The AAT was developed based on the unit of stellar distance and radiation from the topic area of astrophysics as specified by Rwanda's nation curriculum, advanced level physics syllabus. The initial AAT was made of 45 questions. Prior to data collection, those 45 questions were subjected to experts in astrophysics education (One university lecturer, one Ph.D. student in astronomy, and three master's students in physics education) and secondary school teachers with 5 and above years of experience in teaching physics in secondary schools for validation. Those validators were selected because of their significant experience with Rwanda's secondary school physics curriculum, broad experience with physics research, and/or their immense experience in teaching astrophysics and research in astrophysics education area. Their contributions led to the amendment of the AAT and 37 questions out of 45 were retained. Moreover, the AAT validity was done by experts in the field of education science and ICT in education.

To check the reliability, the pilot study was done on 53 (34 boys and 19 girls) from a school with the similarities settings to the selected schools. The reliability analysis was done by means of exploratory factor analysis using a statistical package for social science (SPSS) version 21. The principal component extraction revealed that 7 items did not meet the criteria since the factor loading was less than .4 and were removed from the instrument. The 30 items retained were subject to internal consistency analysis and given a Cronbach's Alpha of 0.87 which was considered acceptable since is greater than 0.7 recommended *(Taber, 2018).* Moreover, all 30 items they are no pair's inter-item correlations of more than .80, so All 30 questions were independent.

3.4.Procedure

Prior to the intervention, a pre-test using the AAT was administered to all groups to identify the initial differences among groups. After gathering the initial differences among groups, both the experimental and comparison groups were taught the same topic in the topic area of astrophysics. The unit taught was stellar distance and radiation from senior five syllabi with the same length of time for both experimental and comparison groups. Orientation training for teachers from selected schools was organized one week before the start of the intervention. Training focused on the objectives of the study, the topic area, and unit to be taught, the procedural strategies, as well as the general conduct of the study. Moreover, a special training focused on the effective integration of VBM in teaching and learning physics was organized and conducted with teachers in the experimental group independently. During the four weeks of the intervention period, the teachers were supervised by researchers to ensure smooth intervention and learning. The experimental group was taught using VBM while the comparison group was taught using normal teaching methodology. After four weeks of teaching, a post-test was administered in both groups. To answer the questions in both the pre-test and post-test, students worked independently under the invigilation of an assistant researcher and class subject teacher. The time allocated for both pre-test and post-test was 80 minutes which equals two school periods.

3.5.Data analysis

Analysis of collected data was done using SPSS version 21. Descriptive analysis such as standard deviation, mean, percentage, minimum, and maximum were used to analyze data from tests. The inferential statistics such as t-test for means, average normalized gains, p-values, and Cohen's d effect size were also used to communicate the degree of the treatment effect. In all statistical tests, the research hypothesis was accepted or rejected at the significant level of 0.05

4. Research Results

Figure one displays the demographical information of respondents per gender and geographical location (urban or rural). In this study, 294 students participated willingly in this study.

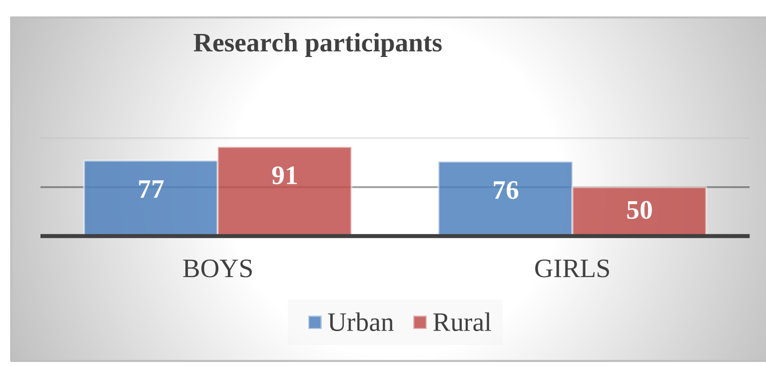

Figure 1: Research participants

In this study, 168 participants were boys while 126 were girls. 141 participants were from rural settled areas and

153 participants were from urban settled areas. 18.1 years old was the average age of participants. During data collection, learners were subjected to the control group and experimental group. Table 1 shows the distribution of learners in control group and experimental group per geographical location and gender

Table 1: Respondents distribution per combination, gender, and district

	Control Group		Experimental Group		Total	
	Boys	Girls	Boys	Girls	Boys	Girls
Rural settled schools	49	33	42	17	91	50
Urban settled schools	43	25	34	51	77	76
Total	92	58	76	68	168	126

Table 1 displays the distribution of participants in the control and experimental groups per geographical location and gender. In rural settled schools, 82 students (49 boys and 33 girls) were in the control group while 59 students (42 boys and 17 girls) were in the experimental group. In urban settled schools, 78 students (43 boys and 25 girls) were in the control group while 85 (43 boys and 51 girls) were in the experimental group. The total number of participants in the control group was 150 students (92 boys and 58 girls) and 144 students (76 boys and 68 girls) were in the experimental group.

The findings displayed in Table 2 reports the overall comparison of learners' results in the control and experimental group before and after the intervention. Results revealed that the intervention (VBM) increased learners' achievement from 27.30 to 53.36 % while normal teaching methods increased learners' achievement insignificantly from 27.03 to 30.46%. In line with the cognitive theory of multimedia, VBM added value to the teaching methods. The lowest earned score was 5 out of 30 on the pre-test in both the experimental and control groups while the highest earned score was 19 out of 30 in the control group and 26 out of 30 in the experimental at post-test. Moreover, the highest SD was 12.13 at the pre-test found in the experimental group and the lowest SD was 8.21 at the post-test found in the control group.

Table 2: Comparison of learners' results before and after intervention

Intervention	N	Test	Average of right answers (30 questions)	%	SD	Min	Max
VBM	144	Pre-test	8.19	27.30	12.13	5	14
		Post-test	16.01	53.36	11.96	11	26
Normal teaching	150	Pre-test	8.11	27.03	9.37	5	15
		Post-test	9.14	30.46	8.21	6	19

Moreover, the t-test, p-value, Cohen's D effect size, and degree of freedom were used to determine the statistical significance of the intervention. The researcher revealed that the effect size is large when is greater than 0.8, medium when is above 0.5, and small when is below 0.2 (Cohen, 1988). Table 3 reports the statistical significance of the two groups before and after the intervention.

Table 3: Statistical significance of groups before and after the intervention

Intervention	Pre-test	Post-test	Av STD	D	<g>	t-test	p-value	Significant	Level
VBM	27.3	53.36	12.04	0.93	0.11	0.000	<0.028	***	Yes
Normal Teaching	27.03	30.46	8.79	0.11	0.01	2.215	>0.05	___	No

To determine the significance of the interventions, Table 3 revealed that the obtained Cohen's D effect size (0.83 for VBM and 0.11 for normal teaching), the average normalized gained (0.11 for VBM Vs 0.01 for normal teaching methods), the t-test and p-values calculated as shown in Table 3 shows that the group of learners taught astrophysics using VBM achieved statistically higher than the group of learners taught the same subject using normal teaching methods from pre-test to post-test

Table 4: Learner's performance in experimental group per gender and school location

	Group	N	Pre-test mean	SD	Post-test mean	SD	Mean gain
Gender	Boys	76	30.21	6.93	54.51	3.36	24.30
	Girls	68	22.70	7.69	50.42	7.36	27.72
School location	Urban	85	27.3	6.83	59.22	8.46	32.19
	Rural	59	28.10	6.87	41.72	7.67	13.62

Table 4 revealed that the pre-test mean scores for boys and girls were 30.21 and 22.70 with a standard deviation of 6.93 and 7.69 respectively. The mean post-test score of boys was 54.51 with a standard deviation of 6.36 while that of females was 50.42 with a standard deviation of 7.36. The mean gain by boys and girls was 24.30 and 27.72 respectively. The difference in the mean gained by boys and girls was 3.42 in favor of girls. This implies that the girls performed better than boys when learning astrophysics using VBM.

Table 4 also shows that the pre-test means scores for urban and rural were 27.03 and 28.10 with a standard deviation of 6.83 and 6.87 respectively. The mean post-test score of urban students was 59.22 with a standard deviation of 8.46 while that of rural students was 41.72 with a standard deviation of 7.67. The mean gain by urban and rural students was 32.19 and 13.62 respectively. The difference in the mean gained by urban and rural students was 18.58 in favor of urban students. Thus, urban students performed higher than rural students when VBM was used.

5. Discussion

Based on the results of this study, it has been noted that learners taught astrophysics using VBM strategies performed much better than learners taught astrophysics using normal strategies of teaching. Hence, we reject the null hypothesis that there is no statistically significant difference in mean achievement scores in astrophysics of learners taught astrophysics using VBM and those taught astrophysics using the teachers' usual teaching strategies. Recent studies echo similar findings that students exposed to learning physics using VBM performed better thanstudents taught physics using teachers' usual teaching methodology (Gustafsson, 2013; Kettle, 2020; Stefan Richtberg, 2018). The statistically significant difference between the experimental group and control group in those selected schools could be attributed to the fact that the learners in the experimental group, the VBM group, were more motivated and actively involved in knowledge construction than the learners in the control group, normal teaching methodology group, that was dominated by chalk and talk, question and answer, and memorization of concepts. These reasons are supported by recent studies on the potential of teaching using video-based multimedia on someone's long-term memory (Erduran, Loannidou, & Baird, 2021), the effectiveness of multimedia in teaching and learning science in general, and the effectiveness of VBM in physics education in particular (Gustafsson, 2013; Herliantari et al., 2019; Mayer R. E., 2020; Ndihokubwayo et al., 2020).

The study revealed that girls' performance is marginally higher than boys' when taught astrophysics using VBM. This means that VBM enhanced girls' performance more than boys' in learning astrophysics content in those selected schools. Researchers reported similar findings on the effectiveness of VBM in physics education in favor of girls (Cowern, 2016; Schrader et al., 2021). However, these findings differ from the findings in the last decades that boys performed better than girls when multimedia is used in teaching and learning. This was due to the unequal access to ICT tools between boys/males and girls/females in the past (Passig & Levin, 2001). The likely reasons for the girls' better performance than boys when VBM is used in teaching and learning astrophysics could be attributed to two main reasons: first is the political will of the government of Rwanda to overcome all gender-based gaps in all corners of life, the pledge to endorsing gender equity, and the empowerment of women by country's top leadership (Gender Monitoring Office [GMO], 2019). Second is equal access to ICT tools for girls and boys (MINEDUC, 2016). This one is supported by the theory of Zajenc that the time spent on an object such as a computer changes someone's attitude and hence becomes familiar with that object (Ukezono et al., 2015).

On the side of school location, rural or urban, the results of this study revealed that urban students had considerably higher performance than their rural counterparts when taught astrophysics using VBM. Further analysis showed that the difference in the mean performance scores between urban and rural students when using VBM in teaching and learning astrophysics was statistically significant. Thus, geographical location was a significant factor in terms of learners' performance of astrophysics content when taught using VBM. Researchers reported similar findings that urban students and rural students show different attitudes toward STEM education (Astalini et al., 2020) and that urban students have access to the latest cutting-edge technology (Wang,

2013) and more motivation towards technology (Li et al., 2015) which is due to the urban environment-based facilities (Chen & Liu, 2013).

6. Conclusion and Implication

In this study, we tested the effectiveness of VBM as an instructional tool for enhancing learners' performance in astrophysics. The findings of this study show a statistically significant difference for VBM over usual teaching methods. Therefore, we conclude that VBM is highly beneficial for teaching and learning physics in general, and astrophysics in particular for Rwanda secondary school physics students. This study also tested the impact of VBM on gender and school location. The results show that girls performed better than boys and urban students performed higher than rural students' counterparts when exposed to VBM in teaching and learning astrophysics. Therefore, we recommend physics teachers adopt VBM especially when teaching abstract topics such as astrophysics. This will allow their learners to learn physics using innovative teaching methodology with a higher probability of enhancing learners' performance. The findings of this study also showed that VBM as an instructional tool to enhance learners' performance is not gendered bias, this stresses another reason why VBM could be integrated in teaching and learning physics in Rwanda secondary schools. However, special attention could be paid to the side of rural schools when integrating multimedia such as VBM in school as the results of this study show a big difference in learners' performance compared to their counterparts in urban schools.This study gives a benchmarking to the effectiveness of utilizing ICT multimedia such as VBM not only in Rwanda but also in other countries nurturing technology in the education system. In fact, decisions to integrate ICTs multimedia related approaches in education in many less developed counties have been taken based on research done in other countries having advanced levels of technology. To this, the results have not been as good as expected and teachers resist integrating it in teaching and learning activities. This study is a novelty in the way that it shows the baseline points to consider especially in developing countries like Rwanda before taking the decision to incorporate VBM in education. Further research should examine the causes of teachers' resistance to incorporating VBM, challenges associated with technology integration in teaching and learning, and possible ways to alleviate those challenges. Learners' attitudes toward the integration of technology-based approaches and teachers' technological content knowledge in education could be another point that needs more research.

7. Conflict of Interest

The authors declare no conflict of interest

8. References

Acker, S., & Oatley, K. (1993). Gender Issues in Education for Science and Technology: Current Situation and Prospects for Change. *Canadian Journal of Education / Revue canadienne de l'éducation*, 255-272 . https://doi.org/10.2307/1495386

Alokan, F. B., & Arijesuyo, A. E. (2013, September). Rural and Urban Differential in Student's Academic Performance among Secondary School Students In Ondo State, Nigeria. *Journal of*

Educational and Social Research. https://doi.org/10.5901/jesr.2013.v4n3p213

Alvarado, I. (2012). *The Important Role of Physics in Industry and Economic Development.* Texas: American Physical Society.

Arztmann, M., Hornstra, L., Jeuring, J., & Kester, L. (2023). Effects of games in STEM education: a metaanalysis on the moderating role of student background characteristics. *Studies in Science Education, 59*(1), 109-145. https://doi.org/10.1080/03057267.2022.2057732

Astalini, A., Kurniawan, D. A., Darmaji, D., & Anggraini, L. (2020, June). Comparison of Students' Attitudes in Science Subjects In Urban And Rural Areas. *Journal of Educational Science and Technology, 6*(2), 126-136. https://doi.org/10.26858/est.v6i2.12057

Avery, L. M. (2013). Rural Science Education: Valuing Local Knowledge. *Theory into Practice, 52*(1), 28-35. https://doi.org/10.1080/07351690.2013.743769

Bram, M., Fleming, M., & Sheils, J. (2023). *Quality & Equity in Education: A pratical guide to the council of Europe vision of education for plurilingual, intercultural, and democratic citizenship.* Multilingual matters.

Byusa, E., Kampire, E., & Mwesigye, A. R. (2020). Analysis of Teaching Techniques and Scheme of Work in Teaching Chemistry in Rwandan Secondary Schools. *EURASIA Journal of Mathematics, Science and Technology Education, 16*(6), 1-9. https://doi.org/10.29333/ejmste/7833

Byusa, E., Kampire, E., & Mwesigye, A. R. (2021). A case study of chemistry classroom practices in the Rwandan secondary schools. https://doi.org/10.1016/j.heliyon.2021.e07352

Casselman, M. D., Eichler, a. F., & Atit, K. (2021). Advancing Multimedia Learning for Science:Comparing the Effect of Virtual Versus Physical Models on Student Learning about Stereochemistry. *Science Education*, 1285-1314. https://doi.org/10.1002/sce.21675

Chen, R. S., & Liu, I. F. (2013). Research on the Effectiveness of Information Technology in Reducing the Rural-Urban Knowledge Divide. *Computers and Education*. https://doi.org/10.1016/j.compedu.2013.01.002

Chen, Y.-H. (2011). Cognitive Diagnosis of Mathematics Performance between Rural and Urban Students in Taiwan. *Assessment in Education: Principles, Policy & Practice , 19*(2), 193-209. https://doi.org/10.1080/0969594X.2011.560562

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* . New York: Lawrence Erlbaum Associates.

Cowern, D. L. (2016). Physics Girl Experience—Using YouTube to Teach Acoustics and Wave Physics. *The Journal of the Acoustical Society of America, 140*(4). https://doi.org/10.1121/1.4970555

David, H. (2015). A role for physicists in STEM education reform. *American Journal of Physics*

83, 101 (2015); https://doi.org/10.1119/1.4904763, 83, 101-109. doi:10.1119/1.4904763

Dusen, B. V., & Nissen, J. (2020). Equity in College Physics Student Learning: A Critical Quantitative Intersectionality Investigation. *Journal of Research in Science Teaching*. https://doi.org/10.1002/tea.21584

Ellermeijer, T., & Tran, T. B. (2019). Technology in Teaching Physics: Benefits, Challenges, and Solutions. In M. Pietrocola, *Upgrading Physics Education to Meet the Needs of Society* (pp. 35-67). Gewerbestr. 11: Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-319-96163-7_3

Erduran, S., Loannidou, O., & Baird, J.-A. (2021). The impact of epistemic framing of teaching videos and summative assessments on students' learning of scientific methods. *International Journal of Science Education, 43*(18), 2885-2910. https://doi.org/10.1080/09500693.2021.1998717

GMO. (2019). *The State of Gender Equality in Rwanda, from Transition to Transformation.* Kigali: GENDER MONITORING OFFICE.

Gossuin, Y., Hocq, A., Gillis, P., & Vuong, Q. L. (2010, June). Physics of Magnetic Resonance Imaging: From Spin to Pixel. *Journal of Physics and Applied Physics , 43*(21). https://doi.org/10.1088/0022-3727/43/21/213001

Guan, N. H., Bunyamin, M. A., & Khami, N. (2020). Perspectives of STEM Education from Physics Teachers' Points of View: A Quantitative Study. *Universal Journal of Educational Research*, *8*(11 C), 72-82. https://doi.org/10.13189/ujer.2020.082309

Gustafsson, P. (2013). How Physics Teaching is Presented on YouTube Videos. *Educational Research for Social Change*, *2*(1), 117-129.

Halliday, D., Resnick, R., & Walker, J. (2013). *Fundamentals of Physics*. Hoboken, New Jersey, United State: Wiley.

Harris, R. S., & Hodges, C. B. (2018). STEM Education in Rural Schools: Implications of Untapped Potential. *National Youth Advocacy and Resilience Journal*.

Herliantari, H., Abdurrahman, & Herlina, K. (2019). Teachers Perceptions and Anxiety about Using Multimedia in Learning Geometry Optics Concept: A Preliminary Research on STEM Learning Makerspace. *The 9th International Conference on Theoretical and Applied Physics (ICTAP).* Bandar Lampung: IOP Publishing. https://doi.org/10.1088/1742-6596/1572/1/012066

IES, I. o. (2012). *A Study of the Effectiveness of a School Improvement Intervention (Success in Sight).* National Center for Education Evaluation and Regional Assistance. Washington, DC: U.S. Department of Education.

Jajuri, T., Hashim, S., Ali, M. N., & Abdullah, S. M. (2019). The Implementation of Science, Technology, Engineering and Mathematics (STEM) Activities and Its Effect on Student's Academic Resilience. *Asia Pacific Journal of Educators and Education, 34*, 153–166. https://doi.org/10.21315/apjee2019.34.8

Jia, C., Yang, T., Qian, Y., & Wu, X. (2020). The Gender Differences in Science Achievement, Interest, Habit, and Creativity. *Science Education International*, *31*(2), 195-202. https://doi.org/10.33828/sei.v31.i2.9

Kahle, J. B., Parker, L. H., Rennie, L. J., & Riley, D. (2010). Gender Differences in Science Education: Building a Model. *Educational Psychologist* , *28*(4), 379-404 . https://doi.org/10.1207/s15326985ep2804_6

Kettle, M. (2020). How videos are used in secondary school physics teaching. *Physics Education*.

Kristensen, H. M. (2016, February 8). *The Basics of Nuclear Weapons: Physics, Fuel Cycles, Effects and Arsenals.* (N. I. Director, Performer) Federation of American Scientists, Washington, D.C, Washington, D.C, USA.

Kuna, S. L., & Prasad, A. K. (2019, June). Research Methodologies for Student Performance Evaluation Using Educational Analytics Tools and Approaches. *International Journal of Recent Technology and Engineering (IJRTE), 8*(1S4), 68-74.

Lacambra, W. T. (2016). Students' Academic Performance in Physics 1: Basis for Teaching and Learning Enhancement. *Research on Humanities and Social Sciences, 6*(4), 78-84.

Li, J., Snow, C., & White, C. (2015). Urban Adolescent Students and Technology: Access, Use and Interest in Learning Language and Literacy. *Innovation in Language Learning and Teaching* , *9*(2), 143-162. https://doi.org/10.1080/17501229.2014.882929

Lindner, M. A., Schult, J., & Mayer, R. E. (2020). A Multimedia Effect for Multiple-Choice and Constructed-Response Test Items. *Journal of Educational Psychology*. https://doi.org/10.1037/edu00006461

Makarova, E., Aeschlimann, B., & Herzog, a. W. (2019, July). The Gender Gap in STEM Fields: The Impact of the Gender Stereotype of Math and Science on Secondary Students' Career Aspirations. *Frontiers Education*. https://doi.org/10.3389/feduc.2019.00060

Marcus, M., Solis, G., Sellars, S., & Haden, C. A. (2023). Promoting children's science, technology, engineering, and mathematics learning at home through tinkering and storytelling. *Frontiers in Phychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1146063

Mayer, R. (2014). Incorporating Motivation Into Multimedia Learning. *Learning and Instruction*, *29*, 171-173. https://doi.org/10.1016/j.learninstruc.2013.04.003

Mayer, R. E. (2020). *Multimedia Learning* (3rd edition ed.). Santa Barbara: University of California, . https://doi.org/10.1017/9781316941355

Mbonyiryivuze, A., Yadav, L. L., & Amadalo, M. M. (2021, June). Students' Attitudes Towards Physics in Nine Years Basic Education in Rwanda. *International Journal of Evaluation and Research in Education (IJERE), 10*(2), 648~659. https://doi.org/10.11591/ijere.v10i2.21173

Meissel, K., Meyer, F., Yao, E., & Davies, C. R. (2017, July). Subjectivity of Teacher Judgments: Exploring Student Characteristics that Influence Teacher Judgments of Student Ability. *Teaching and Teacher Education, 65*, 48-60. https://doi.org/10.1016/j.tate.2017.02.021

MINEDUC. (2016). *ICT IN Education policy.* Kigali: RWANDA MINISTRY OF EDUCATION.

Mineduc. (2020). *Keeping the Doors Open for Learning: Response Plan of Ministry of Education to the COVID-19 Outbreak.* Kigali: Rwandan Ministry of Education.

MolokoMphale, L., & Mhlauli, M. B. (2014). An Investigation on Students Academic Performance for Junior Secondary Schools in Botswana. *European Journal of Educational Research, 3*(3), 111-127.

Morris, J., Slater, E., Fitzgerald, M. T., Lummis, G. W., & Etten, E. v. (2021). Using Local Rural Knowledge to Enhance STEM Learning for Gifted and Talented Students in Australia. *Research in Science Education, 51*, 61-79.

Mugiraneza, J. P. (2021). *Digitalization in Teaching and Education in the Context of COVID-19: Rwanda. Digitalization, the Future of Work and the Teaching Profession Project.* Geneva: International Labour Organization.

Mukuka, A., Mutarutinya, V., & Balimuttajjo, S. (2019). Exploring the Barrirs to Effective Cooperative learning Implementation in School Mathematics Classroom. *Problems of Education in 21st Century, 77*(6), 745-757.

Mukuka, A., Shumba, O., & Mulenga, H. M. (2021). Students' experiences with remote learning during the Covid-19 school closure: implications for mathematics education. *Heliyon*.

Mushinzimana, X., & Sinaruguliye, J. d. (2016). Attitude of Physics Students towards Physics at College of Science and Technology – University of Rwanda. *Rwanda Journal of Education, 3*(2).

Ndihokubwayo, K., Uwamahoro, J., & Ndayambaje, I. (2020). Effectiveness of PhET Simulations and YouTube Videos to Improve the Learning of Optics in Rwandan Secondary Schools. *African Journal of Research in Mathematics, Science and Technology Education, 24*(2), 253-265. https://doi.org/10.1080/18117295.2020.1818042

Pandey, D. (2020). *Understanding Physics for JEE Main and Advanced Electricity and Magnetism* (Seventeen edition ed.). Haldwani, Haldwani, India: Arihant Publication Pvt. Ltd.

Park, Y. S., Konge, L., & Artino, A. R. (2019, November). The Positivism Paradigm of Research. *Academic medicine: journal of the Association of American Medical Colleges , 95*(5), 690-694.

https://doi.org/10.1097/ACM.0000000000003093

Passig, D., & Levin, H. (2001). The Interaction between Gender, Age, and Multimedia Interface Design. *Education and Information Technologies, 6*, 241–250.

Passing, D., & Levin, H. (2001). The Interaction between Gender, Age, and Multimedia Interface Design. *Education and Information Technologies*, 241–250.

REB, R. E. (2015). *Competence based Curriculum, Curriculum for Sustainable Development.* Kigali: REB.

Rovelli, C. (2016). *Seven Brief Lessons on Physics.* New York City: Riverhead Books.

Saw, G. K., & Agger, C. A. (2021). STEM Pathways of Rural and Small-Town Students: Opportunities to Learn, Aspirations, Preparation, and College Enrollment. *Educational Researcher*. https://doi.org/10.3102/0013189X211027528

Schrader, C., Seufert, T., & Zander, S. (2021). Learning From Instructional Videos: Learner Gender Does Matter; Speaker Gender Does Not. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2021.655720

Serrano, M. J., & Rodríguez, J. M. (2020). Interest in STEM Disciplines and Teaching Methodologies. Perception of Secondary School Students and Preservice Teachers . *Educar*, *56*(2), 369-386.

Seyranian, V., Madva, A., Duong, N., Abramzon, N., Tibbetts, Y., & Harackiewicz, J. M. (2018). The Longitudinal Effects of STEM Identity and Gender on Flourishing and Achievement in College Physics. *International Journal of STEM Education, 40*.

Stefan Richtberg, R. G. (2018). Learning Physics with Interactive Videos – Possibilities, Perception, and Challenges. *GIREP-MPTL 2018.* San Sebastian: IOP Publishing. https://doi.org/10.1088/1742-6596/1287/1/012057

Stoet, G., & Geary, D. C. (2018). The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education. *Psychological Science*. https://doi.org/10.1177/0956797617741719

Taber, K. S. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education, 48*, 1273–1296.

Tyson, N. d. (2017). *Astrophysics for People in a Hurry* (1st Edition ed.). midtown Manhattan, New York, United State: W. W. Norton & Company.

Ukezono, M., Nakashima, S. F., Sudo, R., Yamazaki, A., & Takano, Y. (2015). The Combination of Perception of other Individuals and Exogenous Manipulation of Arousal Enhances Social Facilitation as an Aftereffect: Re-Examination of Zajonc's Drive Theory. *Front. Psychol*. https://doi.org/10.3389/fpsyg.2015.00601

UNESCO. (2020). *Empowering Students with Disabilities during Covid-19 Crisis* . Glob. Educ.

Coalition. Retrieved from https://en.unesco.org/covid19/educationresponse/globalcoalition.

UNICEF. (2020). *Education and COVID-19.* United Nations Children's Fund.

Vali, I. (2013, April). The Role of Education in the Knowledge-based Society. *Procedia - Social and Behavioral Sciences, 75*(15), 388-392. https://doi.org/10.1016/j.sbspro.2013.04.133

Wang, P.-Y. (2013). Examining the Digital Divide between Rural and Urban Schools: Technology Availability, Teachers' Integration Level and Students' Perception. *Journal of Curriculum and Teaching, 2*(2), 127-139.

Weinberger, P. (2013). The discovery of thermodynamics. *Philosophical Magazine, 93*(20), 2576-2612. https://doi.org/10.1080/14786435.2013.784402

WHO. (2020). *Coronavirus Disease (COVID-19) Pandemic.* World Health Organisation. Retrieved from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen.

WHO. (2021). *Corona Virus Disease (Covid-19) Dashboard.* Geneva: World Healf organization. Retrieved from https://covid19.who.int/table.

Wolf, M. (2016). *The Physics of Computing* (1st Edition ed.). Burlington, Massachusetts, United States: Morgan Kaufmann.

Wolf, S., Mccoy, D. C., & Godfrey, E. B. (2016, June). Barriers to School Attendance and Gender Inequality: Empirical Evidence From a Sample of Ghanaian School Children. *Research in Comparative and International Education, 11*(2), 178 –193. https://doi.org/10.1177/1745499916632424

Wu, C., DeBoer, J., Rhoads, J. F., & Berger, E. (2021). Use of Worked-Example Videos to Support Problem-Solving: An Analysis of Student Behavior. *Computer Applications in Engineering Education,* 1-27. https://doi.org/10.1002/cae.22451

Zendler, A., Seitz, C., & Klaudt, D. (2018). Instructional Methods in STEM Education: A Cross-contextual Study. *EURASIA Journal of Mathematics, Science and Technology Education, 14*(7), 2969-2986. https://doi.org/10.29333/ejmste/91482