JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website: www.jriiejournal.com ISSN 2520-7504 (Online) Vol.10, Iss.2, 2026 (pp. 708 - 717)

Exploring Biology teachers' Pedagogical Knowledge and Skills in Using Teaching and Learning Resources to Enhance Students Learning Interaction

Donatha Uzayisenga[1], Ezechiel Harerimana[2] & Felex Dushimimana[3]
[1,2] African Centre of Excellent for Innovative Teaching and Learning Mathematics and Science (ACEITLMS),
[3]University of Rwanda- College of Education (UR-CE), Department of Mathematics, Sciences and Physical Education
Email: harerimana.ezechiel@yahoo.com

Abstract: *This study investigated biology teachers' pedagogical knowledge and skills in using teaching and learning resources to enhance student learning interaction in selected upper secondary schools of Ngoma District, Rwanda. It was guided by the following specific objectives of this study were: (1) to identify the teaching and learning resources used in biology education, and (2) to explore biology teachers' pedagogical knowledge and skills in using teaching and learning resources. A descriptive qualitative design was used, involving 12 biology teachers purposively selected from 14 upper secondary school biology teacher participants in Ngoma District, with data collected through classroom observations and semi-structured interviews. Findings show that animation, laboratory equipment and textbooks are the most frequently used resources, while virtual laboratories and specimens are rarely used. Teachers demonstrate limited pedagogical skills in integrating resources, with weak use of collaborative, inquiry-based and demonstration strategies. Overall, only a minority of teachers effectively apply resource-based pedagogy, largely due to insufficient training and resource constraints. The study concludes that Biology teaching in upper secondary schools uses diverse resources like animations, laboratories and textbooks but integration is uneven, with limited use of advanced tools, suggesting that effective implementation of the competence-based curriculum requires not only availability of resources but also strong pedagogical competence among teachers to promote interactive collaboration, in biology lessons. Therefore, continuous in-service training, improved access to laboratory and ICT-based tools are recommended to bridge the gap between policy expectations and classroom practice in biology education in Ngoma District and similar context.*

Keywords: *Teaching and learning resources, Biology teachers' pedagogical knowledge and skills, use of teaching and learning resources.*

How to cite this work (APA):

Uzayisenga, D., Harerimana, E. & Dushimimana, F. (2026). Exploring Biology teachers' Pedagogical Knowledge and Skills in Using Teaching and Learning Resources to Enhance Students Learning Interaction. *Journal of Research Innovation and Implications in Education, 10*(2), 708 – 717. **https://doi.org/10.59765/cfr9**

1. Introduction

Bušljeta (2013) and Adjei (2019) argued that teaching and learning resources are materials that are used by teachers for presenting and delivering and delivering the required education content such as: visual like images, photographs, maps diagrams, audio and audio-visuals. Burnheim (1992), Cooper (1993) and Cooper&McIntyre (1996) pointed out

teaching and learning resources are structured motivated learning activities that are planned and provided by teachers in adaptable ways referring to the students' needs. Febriani & Fikri (2015); Butler (2012), Ahmadet al (2019) said that teaching and learning resources are manifold materials developed to facilitate knowledge and skills' acquisition.

Apau (2016), Kafyulilo et al (2016) argued that pedagogical knowledge and skills of teaching and learning resources allow teachers to select, to organize and integrate relevant resources that create a stimulating classroom that enhance students' interaction. The study by Bušljeta (2013) indicated three stages such as select the resources 'types that align with the objective biology lessons and students' needs, presentation and interpretation to promote classroom interaction and evaluation.

In Africa countries, the study by Okori and Jerry (2017) affirmed that effective use of teaching and learning resources improve academic performance. Similarly, Olayinka (2016); and Francis and Modestus (2020) found that the students taught by using teaching and learning resources performed well than students who taught without using teaching and learning resources. The study by Omariba et al (2017) argued that the effective use of resources was not only the factor that enhance academic achievement but there are other factors such as teachers' qualification and pedagogical knowledge and skills.

In Rwanda, Mukagihana et al (2020) revealed low-level of availability of biological teaching and learning resources. The study of Ndayambaje et al (2021); and Muhoza et al (2023) found that it is essential to note that factors beyond biological resources such as insufficient teaching and learning resources, inappropriate teaching strategies and students' attitude may act as barrier for students learning improvement. The study by Mukagihana et al (2021) claimed that lack or improper use of teaching and learning resources make biology lessons less enjoyable for students learning outcomes. Yet, the current study investigated biology teachers' pedagogical knowledge and skills apply in using teaching and learning resources to improve students learning and classroom interaction.

1.1 Statement of Research Problem

In 2015, Rwandan transitioned from knowledge-based curriculum to competence-based curriculum (CBC) to equip learners with practical skills and suitable competences for 21st century (REB, 2015). Although, the implementation of this CBC challenged biology teachers as they are required to shift from theory to practices with highlighting the use of teaching and learning resources for raising students learning interaction (Nsengimana et al, 2020). The study by Orodho and Benjamin (2014), Nsengimana (2021), Adongo et al (2024) indicated that lack or inadequate of biology teachers' pedagogical knowledge and skills apply in using teaching and learning resources in biology lessons.

Rwandan recent study was conducted to use of teaching and learning resources to the students' performance (Muhoza et al, 2023; Mukagihana et al, 2021). The current study bridged the gap by investigating biology pedagogical knowledge and skills apply in using teaching and learning resources in biology lessons. The researcher was motivated to conduct this study due to the number of motives. First, the implementation of new biology competence-based curriculum that required the use of teaching and learning resources to enhance students learning interaction (REB, 2015). Second, the study wanted to investigate biology teachers' pedagogical knowledge and skills apply in using teaching and learning biology to improve students learning interaction. Yet, due to inappropriate use of biology resources, loss of interest of biology lessons and interactivity for students learning in lower secondary schools. Therefore, the current study, intended to investigate the biology teacher's pedagogical knowledge and skills apply in using teaching and learning resources to enhance students learning interaction.

The purpose of this study was to investigate teaching and learning resources of biology and biology teachers' pedagogical knowledge and skills to improve students learning interaction in selected upper secondary schools of Ngoma District. The specific objectives of this study were: (1) to identify the teaching and learning resources used in biology education, and (2) to explore biology teachers' pedagogical knowledge and skills in using teaching and learning resources. The study was guided by the following research questions: (1) What teaching and learning resources are used in biology education? and (2) What are biology teachers' pedagogical knowledge and skills in using teaching and learning resources?

2. Literature Review

2.1. Types of Teaching and Learning Resources

According to Obomanu (2011) teaching and learning resources are all materials helped by teachers to facilitate leaning process in classroom. The study from Burnheim et al (1992) defined teaching and learning resources are structured education activities in which students assumed their responsibilities for the information transmission process. The difference authors Broun and Wragge (1993) as cited in Ong'amo et al (2017) grouped resources into various groups such as visual, audio and audio-visual. described teaching and learning resources. However, the current study focuses on physical and technological resources.

Physical resources are real materials that are used to support teaching and learning. These resources include Textbooks, laboratory equipment, models, and charts, while technological resources are teaching and learning materials that use both sight and hearing. They use multisensory materials such as animation, simulation, charts, model and physical environmental resources and laboratory equipment (Muhoza et al 2023). Laboratory equipment refers

Laboratory equipment refers to the field of science in which learners improve their comprehension idea from science. Laboratory equipment includes microscopes, chemicals and various materials (Warwick, 1974; Constraints 1993; Hofstein & Lunetta, 2004).

Models are visual resources. They can hard or soft such as posters, living organism and images that are used to support teaching and learning process and to improve teaching and to improve comprehensions and communication (Jančaříková & Jančařík, 2017).

Charts are visual resources to organize, present and simplify complex information. It can take different forms such diagrams, graphs and tables. Textbooks are printed resources that include the fundamental ideas of a practical, artistic, or scientific endeavor. Robert dictionally described it as instructional writing, in an easily accessible style, with necessary scientific concepts and methods, particularly the knowledge needed for the course of study (Pop-Pacurar & Ciascai, 2010).

Virtual laboratories are complimentary resources that simplify instruction and comprehension for students (Durkaya, 2022). Yet, Virtual laboratories are similarly successful as real physical laboratories in increasing students' understanding and knowledge (Lewis, 2014).
Simulation refers to simulated environments that reflect how students apply their skills, not an imitation of a happening designed to help learners build conceptual knowledge around the event exhibited (Kappers et al, 2016). However, Landriscina (2013) Simulation is an interactive system model that embodies abstract concepts under the study.
According to the study by Kanda (2022), animation is defined as a computer-generated motion film where images or items are altered to appear for moving. Thus, in education, animation is a very beneficial approach to learning with several advantages over immobile visuals; as a result, students who learn using animation excel in their studies.

2.2. Contribution of teaching and learning resource in biology lessons

Quasthoff et al (2018) suggested that classroom interaction is a type of spoken interaction or classroom converse. It is a learning atmosphere that makes topic-matter instructing possible. Similarly, Hymes (1972) and Koole (2015) argued that classroom interaction is examined from the standpoint of social interaction to identify the methods by which educators and students carry out their activities during the teaching and learning process.Thus, teaching and learning resources encompass diverse materials related to biological concepts. Bušljeta (2013) also emphasized that teaching and learning resources facilitate engaging interactions between teachers and students, and students among themselves.
Similarly, Olayinka (2016) asserts that instructional materials promote fascinating, practical, reliable, and engaging learning experiences. For example, studies have demonstrated the positive impact of virtual laboratories on student understanding and interaction (Balamuralithara & Woods, 2007; Mikropoulos et al, 2003). However, Lewis (2014) found that virtual laboratories cannot entirely replace traditional laboratories in biology education though, they supplement one another. Therefore, virtual laboratories need to address issues related to inadequate or insufficient laboratory equipment for certain biology topics. Consequently, students' engagement, collaboration, and participation improved.

The study from Sasikala & Tanjong (2016) indicated the high contribution of simulation students' interest if it is more used effectively in teaching and learning biology. Like the study from Türkmen (2001) indicated that the appropriate use of simulation highly contributes to enabling students to correct the issues related to real-world experience while learning biology. Additionally, simulation reduces the problem of time-consuming and expensive laboratory experiments to stimulate students 'interaction (Türkmen, 2001). Stith (2004) argued that the advantages of animation are more evident for some visual students. Teaching using animation in biology improves student-student and teacher-student interaction in which students' engagement, exploration, and collaboration increase. As well as animation aids in simplifying understanding and visualizing topics that are difficult to describe through static images particularly, in the biology process.

In biology class, laboratory equipment is paramount for learners to comprehend concepts through hands-on experiences (Antonio, 2018). Therefore, laboratory equipment progresses critical thinking, problem-solving, and creativity skills among students (Antonio, 2018). Thus, the development of these skills improves students' interaction. Besides, these resources help learners to visualize and understand abstract and frustrating concepts (Mer, 2007).

2.3. Biology teachers' pedagogical knowledge and skills in using teaching and learning resources

Teachers' strong pedagogical knowledge enhances communication among teachers and students, as well as among students themselves, through the effective use of biology teaching and learning resources (Barnett & Hodson, 2001). Such pedagogical competence enables teachers to select, organize, and integrate relevant instructional materials, thereby creating a stimulating classroom environment that promotes active student interaction (Apau, 2016; Kafyulilo et al., 2016). Further argue that instructional resources play a key role in facilitating communication between educators and learners, while also encouraging active participation in learning. Consequently, research suggests that the effective use of teaching and learning resources can significantly enhance student interaction in biology classrooms (Obomanu, 2011).

This study is important for learners as it encourages the use of instructional resources that support the construction of their own knowledge and skills through collaboration, engagement, and active learning (Olusegun, 2015; Akpan et al., 2020; Kouicem, 2020). This view is supported by Vygotsky's social constructivist theory (1968), which emphasizes that learners construct knowledge through social interaction and learning experiences when appropriate teaching and learning resources are effectively used, thereby promoting active and meaningful learning (Olusegun, 2015; Kouicem, 2020).

3. Methodology

3.1 Research design

The study used a descriptive qualitative research design. This design was appropriate because the study aimed to explore and understand Biology teachers' pedagogical knowledge and skills in using teaching and learning resources. It allowed the researcher to collect detailed information on teachers' classroom practices, experiences, and perspectives without manipulating variables.

3.2 Target population

The target population consisted of all Biology teachers in upper secondary schools offering Biology option within 12 Years Basic Education (12YBE) in Ngoma District. Specifically, the study focused on schools across 14 sectors in Ngoma District where Biology is taught at upper secondary level. The total target population was 14 Biology teachers who teach Biology in these upper secondary schools.

3.3 Sampling technique and sample size

The study used a purposive sampling technique. This means the researcher intentionally selected participants who had relevant knowledge and experience. From the target population of 14 Biology teachers, a sample of 12 Biology teachers was selected. The selection criteria included: Teaching Biology in upper secondary schools, having at least two years of teaching experience. This ensured that the selected teachers had sufficient experience to provide reliable information for the study.

3.4 Data collection tools and procedures

The study used two main data collection tools: an observation checklist and an interview guide. The observation checklist was used to examine how Biology teachers utilized teaching and learning resources during classroom instruction and how these resources influenced student interaction, while the interview guide helped collect in-depth information about teachers' pedagogical knowledge, skills, challenges and experiences in using such resources.

Before data collection, the researcher obtained permission from relevant school authorities, informed the selected Biology teachers about the purpose of the study, and obtained their signed consent forms. The researcher then attended Biology lessons to observe classroom practices related to the use of teaching and learning resources. After the observations, individual interviews were conducted with the teachers to clarify and expand on the information gathered during classroom observation. All data were collected systematically and recorded for analysis.

3.5 Data analysis

The collected data were analyzed using qualitative thematic analysis, a method that enabled the researcher to systematically interpret participants' experiences and behaviors (Braun et al., 2008). First, data gathered from interviews and classroom observation checklist were carefully organized to ensure clarity and ease of analysis. The researchers then engaged in repeated reading and re-reading of the data to become familiar with the content and identify recurring patterns and ideas. Similar responses, statements and observed behaviors were coded together to highlight meaningful connections within the data. These codes were subsequently grouped into broader themes related to pedagogical knowledge, resource usage and student interaction, which reflected the key areas of the study. Finally, the identified themes were interpreted in relation to the research objectives in order to draw conclusions and provide a deeper understanding of the findings.

3.6. Ethical issues

The study followed key ethical research principles throughout the data collection process. Informed consent was obtained by informing teachers about the purpose of the study and allowing them to participate voluntarily. Confidentiality was maintained by keeping participants' identities and school names private, while anonymity was ensured through reporting data without revealing personal identities. Participation in the study was entirely voluntary, and teachers were free to withdraw at any time without penalty. Additionally, the researcher demonstrated respect by valuing teachers' time, opinions, and professional environment during the research process.

4. Results and Discussion

4.1 Biological teaching and learning resources used in biology education

Our primary research question was: What teaching and learning resources are used in biology education? Aligned with the following objective: to identify the teaching and learning resources used in biology education.

The study identified the types of teaching and learning resources used, as well as the specific units in which these resources are applied.

Table 1: Types of teaching and learning resources and their relevant units

Teaching and learning resources	Units	N	FA(n)	%	FD(n)	%
Laboratory equipment	Identification of food components, Plant cell and animal cell, photosynthesis	12	8	67	4	33
Simulation	Human reproductive system, Heterotrophic nutrition, Passive movement of substances across the cell membrane	12	5	42	7	58
Animation	Heterotrophic nutrition, identification food components, passive movement of substances across the cell membrane	12	9	75	3	25
Biology specimen	Eternal structure and importance of flowering plants	12	2	17	10	83
Charts	Animal and plant cell, External structure and importance of flowering plants, Population size	12	4	33	8	67
Model	Gas exchange in human and plants, Animal and plant cell, Mitosis and meiosis	12	3	25	9	75
Physical environmental resources	External structure and importance of flowering plants, introduction to environmental biology	12	2	17	10	83
Technological-based resources	Animal and plant cell, Heterotrophic nutrition, photosynthesis	12	6	50	6	50
Textbooks	Enzymes, human reproductive system, Population size, mitosis and meiosis	12	5	42	7	58
Virtual laboratories	Genetic	12	1	8	11	92

N=Total number of respondents**, FA(n)=**Frequency agreement number**, FD(n)=** Frequency Disagreement

Source: Primary data, 2025

Table 1 indicates that biology teachers in upper secondary schools use a variety of teaching and learning resources, though the frequency of use differs considerably across resource types and topics. The most frequently used resource is animation, with 75% of teachers reporting its use in units such as heterotrophic nutrition, identification

of food components, and passive movement across cell membranes. This is supported by classroom observations supported by interviews report where animation was particularly evident in topics such as enzyme action, human digestion, and catalytic processes. These findings align with Stith (2004), who emphasizes that animation, especially when combined with sound enhances learners' understanding of abstract biological concepts more effectively than static illustrations, thereby improving conceptual clarity and learner engagement.

Laboratory equipment is also widely used, with 67% of teachers reporting its application in units such as plant and animal cells and identification of food components. Observations confirmed frequent use of chemical tests for starch, lipids and proteins in biology sessions, demonstrating practical engagement with core biological content. This finding is consistent with Isma'il and Akilu (2019), who argue that the availability and use of laboratory resources significantly improve classroom interaction and learners' participation in science lessons. However, despite this relatively strong presence of laboratory work, the data suggests that such resources are still not uniformly integrated across all schools and topics, indicating disparities in practical science delivery.

In contrast, simulation (42%) and textbooks (42%) show moderate usage, while other resources such as models (25%), charts (33%), biology specimens (17%), and physical environmental resources (17%) are less frequently applied. Simulations were mainly used for topics like passive movement across membranes and reproductive systems, while models supported understanding of mitosis, meiosis, and organ systems. These findings suggest that while teachers are gradually incorporating interactive and visual aids, there remains a strong dependence on more traditional instructional materials. Njuguna (2018) supports this observation by noting that effective use of teaching and learning resources enhances learners' motivation and understanding; however, limited use of varied resources may reduce opportunities for deeper conceptual learning.

The least utilized resource is virtual laboratories (8%), followed by biological specimens and environmental resources, both at 17%. These findings are supported by previous research conducted by Shambare (2025), indicating limited adoption of digital laboratory tools in secondary schools. Classroom observations further confirm that virtual laboratories were largely unavailable in most schools, with some lessons relying solely on textbooks and teacher explanations, particularly in topics such as heterotrophic nutrition and digestive health. These findings are also supported by curriculum implementation reports highlighting persistent resource constraints in science instruction (Jr & Hinacay, 2025). Overall, the results reveal a predominantly traditional teaching approach, with stronger reliance on animation, laboratory equipment, and textbooks, while advanced technological tools remain underutilized. These findings are supported by global evidence showing slow integration of ICT in science education. This imbalance suggests the need for improved infrastructure, teacher training, and resource availability.

4.2 Biology teachers' pedagogical knowledge and skills in using teaching and learning resources

Our second research question was: How do biology teachers apply their pedagogical knowledge and skills in using teaching and learning resources? Whose objective was to investigate biology teachers' pedagogical knowledge and skills in using teaching and learning resources to enhance students learning

Table 2: Biology teachers' pedagogical knowledge and skills in using teaching and learning resources

Biology teachers' pedagogical knowledge and skills in using teaching & learning resources	N	FA(n)	%	FD(n)	%
The teachers use physical resources by putting learners in group discussion	12	2	17	10	83
The teachers use teaching and learning resources by putting learners in group discussion	12	1	8	11	92
The teachers use physical and technological resources via demonstration	12	4	33	8	67
The teachers use physical environment resources to let learners make Observation	12	1	8	11	92
The teachers use models to help learners in Observation	12	1	8	11	92
The teachers describe give instruction before using laboratory equipment during experiment	12	1	8	11	92
The teachers use resources to help learners in presentation	12	1	8	11	92
The teachers use physical or technological resources by asking question and answer them	12	1	8	11	92

N=Total number of respondents**, FA(n)=**Frequency agreement number**, FD(n)=** Frequency Disagreement

Source: Primary data, 2025

Table 2 presents findings on biology teachers' pedagogical knowledge and skills in using teaching and learning resources. The results indicate a generally low level of effective integration of these resources, particularly when it comes to structured pedagogical strategies such as group discussion, demonstration, observation, and guided inquiry. For instance, only 17% of teachers reported using physical resources to organize learners into group discussions, while 83% did not apply this strategy effectively. Similarly, only 8% reported using teaching and learning resources to support group discussion, indicating a limited application of collaborative learning approaches supported by instructional materials. These findings suggest that although some teachers are aware of resource-based pedagogy, its consistent classroom application remains weak and uneven.

Further analysis shows that teachers demonstrate slightly better use of demonstration and observation methods, although the levels remain low. Only 33% of teachers reported using physical and technological resources through demonstration, while 67% did not. Likewise, only 8% used environmental resources and models to support learner observation, with 92% failing to apply these approaches. These results imply that learners are not sufficiently exposed to hands-on and inquiry-based learning experiences that are central to biology education. This aligns with Nduwayezu et al. (2022), who argues that inadequate integration of instructional resources limits the effectiveness of science teaching. It also confirms that the pedagogical gap is not only about availability of resources but also about teachers' capacity to select and apply them appropriately.

The findings also reveal weaknesses in teachers' use of resources during laboratory and presentation-based activities. Only 8% of teachers reported giving clear instructions before using laboratory equipment, while 92% did not follow this essential safety and procedural step. Similarly, only 8% used resources to support learner presentations and question-and-answer sessions. This indicates that learner-centered pedagogical strategies are not fully supported through appropriate resource use. However, interview responses revealed that some teachers rely mainly on self-made charts and limited school-provided materials, such as wall charts, due to shortages of technological resources. As noted by Somba and Otieno (2022), the effective use of instructional resources enhances learner engagement and classroom interaction, yet this is constrained in the current context.

Overall, the findings suggest that only a small proportion (about 30%) of biology teachers demonstrate adequate pedagogical knowledge and skills in using teaching and

learning resources, while the majority (about 70%) show limited competence in this area. Classroom observations further confirmed that physical resources are used more frequently than technological ones, largely due to resource scarcity and limited teacher preparedness. Teachers reported reliance on available materials, with one stating that "we mainly use soft models where it is possible" due to lack of diverse biological models. Similar findings were reported by William et al. (2020), who emphasized that instructional resources improve learner interaction and motivation in biology learning. Therefore, improving both resource availability and teachers' pedagogical competence is essential for strengthening effective biology instruction in secondary schools.

5. Conclusion and Recommendation

5.1 Conclusion

The study reveals that biology teaching and learning in upper secondary schools relies on a diverse range of instructional resources, with animation, laboratory equipment, and textbooks being the most frequently used. However, the integration of these resources is uneven across topics and schools, with advanced tools such as virtual laboratories, biological specimens, and environmental resources being minimally utilized. This indicates a predominantly traditional approach to biology instruction, where modern technological resources remain underdeveloped or inaccessible. Furthermore, while some interactive and visual tools are used, their application is not consistent enough to fully support conceptual understanding of abstract biological concepts.

5.2 Recommendation

There is a need to strengthen the integration of diverse teaching and learning resources, particularly digital tools such as virtual laboratories and simulations, through improved infrastructure and increased investment in ICT facilities. Teacher professional development programs should prioritize practical training on resource-based and learner-centered pedagogies to enhance effective classroom implementation. Schools and education stakeholders should also ensure equitable distribution of laboratory equipment and teaching materials to reduce disparities in practical science learning. Additionally, continuous in-service training and mentoring should be provided to improve teachers' pedagogical competence in selecting, adapting and effectively using available resources to promote effective biology learning.(Hardeep, 2018)

References

Adongo, J. A., Opiyo, R. A., & Ouda, J. B. (2024). Assessment of Pre-Primary II Teachers' Resource Development and Utilization Skills for CBC Implementation in Language Activities. *Journal of Innovation and Research in Primary Education*, *3*(2), 121–132.

Adjei, H. (2015). The Impact of Teaching Learning Resources on Teaching Business Management. *European Journal of Business and Managemen*, *7*(21), 71–76.

Agi, U. K., &, & Uba, T. L. (2020). Availability of educational resources for quality assurance in secondary schools. *British Journal of Education, 8*(3), 134–147.

Ahmad Ibrahim, S., Ibrahim, A., Ya, S., & Ado Abdullahi, S. (2019). Improvisation in Teaching and Learning Biology in Senior Secondary Schools: Prospects and Challenges. *International Journal of Scientific Research in Review Paper Multidisciplinary Studies E*, *5*(11), 33–36.

Antonio, V. V. (2018). Science Laboratory Interest and Preferences of Teacher Education Students: Implications to Science Teaching. *Asia Pacific Journal of Multidisciplinary Research*, *6*(3), 57–67. www.apjmr.com.

Balamuralithara, B., & Woods, P. C. (2007). *Virtual Laboratories in Engineering Education : The Simulation Lab and Remote Lab.* Multimedia University: Cyberjaya, Malaysia.

Braun, V., Clarke, V., Braun, V., & Clarke, V. (2008). Using thematic analysis in psychology Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101

Burnheim, Robert ; Floyd, A. (1992*). Resource-Based Teaching and Learning; A Workshop*. Institution Technical and Further Education-TEQ, Queensland (Australia): Library Network Branch. Queensland, Australia.

Bušljeta, R. (2013). Effective Use of Teaching and Learning Resources. *Czech-Polish Historical and Pedagogical Journal*, *5*(2), 55–69. https://doi.org/10.2478/cphpj-2013-0014

Butler, M. (2012*). Resource-based learning and course design: A brief theoretical overview and practical suggestion*s. *Law Library Journal*, *104*(2), 219–244.

Cooper&McIntyre. (1996). Effective Teaching and Learning -Teachers' and Pupils' Perspectives.*Journal of Education for business,1*(1)135-188

Durkaya, F. (2022). Virtual laboratory use in science education with digitalization. *Hungarian Educational Research Journal*, *13*(2), 189–211. https://doi.org/10.1556/063.2022.00141

Francis, E. R., & Modestus, A. (2020). Impact of Instructional Materials on Secondary SchoolsStudents' Academic Achievement in SocialStudies in Kaduna State, Nigeria. *Journal of Educational Assessment and Pedagogical Process, 1*(1),125-158

Haas, P. M., & Haas, E. B. (2002). Pragmatic constructivism and the study of international institutions. In Millennium. *Journal of International Studies, 31*, (3)16-32.

*Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. Science Education, 88(*1), 28–54.

Hymes, D. (1972).*Ethnographic Description and Explanation*. Loshini Naidoo University of Western Sydney, Australia

Jančaříková, K., & Jančařík, A. (2017). Teaching aids and work with models in e-Learning environments. *Electronic Journal of E-Learning*, *15*(3), 244–258.

Kadzera, C. M. (2006). Use of instructional technologies in teacher training colleges in Malawi. In A Doctoral Dissertation. http://scholar.lib.vt.edu/theses/available/etd-05152006-174707/

Kanda, H. S. (2022). Role of Animation in the Education-an Overview. September 2018.

Kappers, W. M., Cutler, S. L., & Cutler, S. L. (2016). *Simulation to Application . The Use of Computer Simulations to Improve Real-World Application of Learning simulation to application . the use of computer simulations to improve real-world*. *7*(1), 64–74.

Koole, T. (2015). Classroom Interaction. *The International Encyclopedia of Language and Social Interaction*, 1–14. https://doi.org/10.1002/9781118611463.wbielsi092

Kouicem, K. (2020). *Psychological & Educational Studies Constructivist Theories of Piaget and Vygotsky:* Implications for Pedagogical Practices. *Psychological & Educational Studies*, *13*(3), 359–372.

Landriscina, F. (2013). Simulation and Learning: A Model-Centered Approach (Vol. 261699231, Issue April).

Jr, A. T. P., & Hinacay, J. J. D. (2025). Teachers' ICT Integration in Science Teaching and Learning Outcomes. *International Journal of Multidisciplinary Research and Analysis (IJMRA)*, *08*(09), 5287–5295. https://doi.org/10.47191/ijmra/v8-i09-42

Lewis, D. I. (2014). *The pedagogical benefits and pitfalls of virtual tools for teaching and learning laboratory practices in the Biological Sciences* (Issue November).

Mer, A. Ç. İ. (2007). Effective Teaching in Science A Review of Literature. *Journal of Education, 4*(1), 20–44

Mikropoulos, T. A., Katsikis, A., Nikolou, E., & Tsakalis, P. (2003). *Virtual environments in biology teaching*. *Journal of Biological Education*, *37*(4), 176–181.

Muhoza, R. N., Imaniriho, D., Nshimiyimana, A., Nkunzabo, E., Ntezimana, N. J. & Batera, P. N. (2023). The effect of Teaching Aids on Students' Performance in Biology Subject in O' level Secondary Schools in Kayonza District. 7, 124–133.

Mukagihana, J., & Aurah, C. M. (2021). *The Effect of Resource-Based Instructions on Pre-service Biology Teachers ' Attitudes towards Learning Biology*. *20*(8), 262–277.

Mukagihana, J., Nsanganwimana, F., & Aurah, C. M. (2020). Biology Instructional Resources Availability and Extent of their Utilization in Teaching Pre-Service Biology Teachers. *African Journal of Educational Studies in Mathematics and Sciences*, *16*(2),17-45.

Ndayambaje, J. B., Bikorimana, E., & Nsanganwimana, F. (2021). *Factors contributing to the students ' poor performance in biology subject : A case study of ordinary level in rural secondary schools of Rwamagana district*.

Nduwayezu, F. (2023). *The effective use of ICT for improving the teaching of Biology subject in selected secondary schools of Rulindo District , Rwanda*. *January 2022*.

Nduwayezu, F., Ngendabanga, C., Murekaze, B., Byishimo, Y., Wenceslas, P., & Ndayambaje, I. (2022). Challenges Preventing Successful Use of ICT for Teaching and Learning Biology in Rwandan Secondary Schools. *Journal of Research Innovation and Implications in Education*, *6*(2017), 166–177.

Neubert, S., & Reich, K. (2006). The Challenge of Pragmatism for Constructivism: Some Perspectives in the Programme of Cologne Constructivism. *The Journal of Speculative Philosophy*, *20*(3), 165–191.

https://doi.org/10.2307/jspecphil.20.3.0165

Nsengimana, T., Rugema Mugabo, L., Hiroaki, O., & Nkundabakura, P. (2020). Reflection on science competence-based curriculum implementation in Sub-Saharan African countries. *International Journal of Science Education, Part B: Communication and Public Engagement*, *1*(1), 1–14. https://doi.org/10.1080/21548455.2020.1778210

Nsengimana, V. (2021). *Implementation of Competence-based Curriculum in Rwanda: Opportunities and Challenges*. *Rwandan Journal of Education*, *5*(1), 129–136.

Quasthoff, U., Heller, V., Prediger, S., & Erath, K. (2018). *Learning in and through classroom interaction : in subject-matter learning*. 1–21, 37-56.

Obomanu, B. J. (2011). Resources for Teaching Secondary School Biology in Bayelsa State of Nigeria. 1(2), 28–35.

Okori, O. A., & Jerry, O. (2017). *Improvisation and utilization of resources in the teaching and learning of science and mathematics in secondary schools in Cross River state*. Global Journal of Educational Research, *16*(1), 21.

Olayinka, A.-R. B. (2016). *Effects of Instructional Materials on Secondary Schools Students' Academic Achievement in Social Studies in Ekiti State, Nigeria*. *World Journal of Education, 6*(1), 32–39.

Olusegun, S. (2015). *Constructivism Learning Theory* : A Paradigm for Teaching and Learning. *Journal of Education, 5*(6), 66–70. https://doi.org/10.9790/7388-05616670

Ong'amo, B., Ondigi, K., & Omariba, A. (2017). Effect of Utilization of Biology Teaching and Learning Resources on Students ' Academic Performance in Secondary Schools in Siaya District – Kenya. *International Journal of Education and Research*, *5*(1), 2–20.

Onu, W., J., Anyaegbunam, N., & U., Uzoigwe, A. (2020). Imp*roving Biology Students' Interest and Achievement through Collaborative Instructional Strategy*. *Journal of Education, Society and Behavioural Science*, *4*(2), 9–20. https://doi.org/10.9734/jesbs/2020/v33i230198

Pop-Pacurar, I., & Ciascai, L. (2010). B Iology School Textbooks and Their Role for. *Acta Didactica Napocensia*, *3*(1), 1–10.

Orodho, J. A., & Benjamin, B. (2014). *Teaching and learning resource availability and teachers effective classroom management and content delivery in secondary schools in Huye District*, Rwanda. *Journal of Education and Practice*, *5*(9), 111–122.

REB. (2015). Competence-Based Curriculum. *15Th International Conference the Knowledge-Based Organization: Behavioral and Social Sciences, Conference Proceedings 4*, *4*, 308–312.

Sasikala, P., & Tanyong, S. (2016). A Study on Simulation Methods in Academic Success with Reference to Teaching Biology for Education Students. *Journal of Education and Practice*, *7*(11), 164–168.

Shambare, B. (2025). Understanding the Adoption of Virtual Labs in Rural Secondary Schools : A Descriptive Analysis of Perceived Usefulness , Ease of Use , and Behavioral Intentions Understanding the Adoption of Virtual Labs in Rural Secondary Schools : A Descriptive Analysis. *The Rural Educator, 46(2), 46*(2), 50–67.

Stith, B. J. (2004). *Use of animation in teaching cell biology*. *Cell Biology Education*, *3*(3), 181–188. https://doi.org/10.1187/cbe.03-10-0018

Isma'il, M., & Akilu, M. (2019). Availability and utilization of instructional resources and students' performance in science education. *Journal of Science Education and Practice*, 5(2), 45–58.

Njuguna, S. (2018). Influence of instructional resources on students' achievement in biology. *International Journal of Education and Research, 6*(3), 101–112.

Somba, W. D., & Otieno, K. O. (2022). Influence of Teaching and Learning Resources on Students ' Academic Performance in Public Secondary Schools in Arusha District Council , Tanzania. *Journal of Research Innovations and Implications in Education*, *6*(2013), 178–189.

Stith, B. J. (2004). Use of animation in teaching biology concepts: Effects on student understanding. *Journal of College Science Teaching, 33*(7), 48–52.

William, O., Ngozi, J., & Anthony, U. (2020). Improving Biology Students ' Interest and Achievement through Collaborative Instructional Strategy. *Journal of Education, Society and Behavioural Science*, *33*(2), 9–20. https://doi.org/10.9734/JESBS/2020/v33i230198