International Journal of Learning, Teaching and Educational Research
Vol. 23, No. 3, pp. 219-247, March 2024
https://doi.org/10.26803/ijlter.23.3.12
Received Jan 9, 2024; Revised Mar 17, 2024; Accepted Mar 26, 2024

Exploring the Challenges and Strategies for Enhancing Biotechnology Instruction in a Modularized Context at University of Rwanda-College of Science and Technology

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Abstract. The globalization of higher education, spearheaded by initiatives like the Bologna Process, has transformed traditional teaching methods, fostering collaboration and interconnectedness among institutions globally. This transformation is evident in Rwanda's higher learning sector, where teaching and learning paradigms have evolved in line with Bologna Process principles. This study delves into the challenges faced by students and lecturers in teaching and learning biotechnology within this framework, and proposes enhancement strategies. Utilising a mixed-method approach, the study examines responses from 111 participants from the University of Rwanda-College of Science and Technology (UR-CST). Data collection involved questionnaires analysed using SPSS, supplemented by insights from focus group interviews and classroom observations. Key findings reveal hurdles that include inadequate facilities, limited connectivity, and weak coordination between academic and administrative bodies. Large class sizes and a lack of awareness regarding diverse learning styles exacerbate challenges. Additionally, time constraints and infrequent assessments hinder effective teaching and learning. To address these issues, the study suggests solutions such as continuous professional development for teachers, optimised time management, and improved laboratory facilities with dedicated personnel. These recommendations aim to enhance the effectiveness of teaching and learning in biotechnology, ensuring students receive quality education despite prevailing challenges.

Keywords: Biotechnology Education; Bologna Process; Higher Education Challenges; Teaching Methods; Improvement Strategies

1. Background of the study

In the contemporary landscape, societal progress across various spheres is markedly pronounced. A pivotal aspect of this advancement lies in the acquisition and application of skills, which increasingly underpin social and economic development (Pietersen et al., 2023). Tertiary education stands out as the primary avenue for cultivating the high-quality competencies requisite for driving such advancement (Ateş, 2020; Chivers & Sleightholme, 2000; Taremwa et al., 2015; Thangeda et al., 2008). Nonetheless, as underscored by Kabanova and Vetrova (2018), scepticism prevails within the labour market regarding the competencies of undergraduate students, particularly in regions where individuals encounter barriers in accessing diverse professions (ACUP, 2015). In light of this, universities are compelled to prioritize the efficacy and calibre of education provision. This necessitates ongoing changes and reforms tailored to enhance tertiary education's effectiveness. The teaching and learning processes within higher education institutions adhere to the Bologna guidelines, which were implemented with the aim of fostering competence among bachelor's degree students, facilitating student mobility, and fortifying quality assurance in higher education institutions (Huisman, 2019).

Amidst these broader considerations, the challenges of teaching biotechnology to university students, with a focus on Rwanda, emerge prominently. Biotechnology education, crucial for equipping individuals with specialised skills pertinent to various industries, encounters distinct hurdles in this context. In Rwanda, as in many African countries, disparities in accessing the labour market persist due to the perceived inadequacies in the quality and efficiency of biotechnology education provided by universities. This scenario underscores the pressing need for critical examination and discussion of the challenges confronting biotechnology education, particularly in the Rwandan context. Issues such as curriculum relevance, practical training opportunities, and alignment with industry requirements warrant close scrutiny. Addressing these challenges necessitates concerted efforts from educational institutions, policymakers, and industry stakeholders to ensure that biotechnology students are adequately prepared to meet the demands of the labour market. Only through collaborative and proactive measures can the quality and efficacy of biotechnology education be enhanced, thereby enabling students to transition into the workforce effectively and contribute meaningfully to the socio-economic development of Rwanda and beyond.

The educational framework underpinning the Bologna Process is intricately woven with the principles of modularity and credit allocation. This modular system divides educational content into independent, non-sequential units which are typically short in duration, as extensively discussed by Dejene and Chen (2019), Laylo et al. (2020), Rahman (2022), and Sarah French (1999). By adopting this approach, universities can readily tailor their curriculum to meet the evolving demands of the labour market, as highlighted by Sarah French (1999). The modular structure places a strong emphasis on addressing the specific needs of students in alignment with market requirements (Dejene & Chen, 2019). Each module is meticulously crafted to cultivate graduates equipped with the requisite knowledge, skills, expertise, and competencies pertinent to distinct sectors of the labour market and society, as advocated by Gubaydullina et al. (2016) and Laylo et al. (2020). Different universities, irrespective of their financial resources and geographical areas, can effectively implement this modular system by customising their modules to cater to the unique needs of their student population and local job market demands. The utilisation of credits within this framework enable universities to flexibly mould the educational experiences of their students, ensuring they acquire the competencies and proficiencies demanded by specific sectors of the labour market and society. This approach critically aligns with the overarching goals of the Bologna Process, facilitating the harmonisation of higher education systems across Europe and beyond, and promoting the mobility, employability, and competitiveness of graduates on a global scale. Therefore, the choice of the Bologna Process in this study is justified by its capacity to foster a dynamic and responsive educational environment, characterised by modularity, credit-based learning, and the tailored development of graduates equipped to thrive in diverse professional landscapes.

The modular system has been deemed as an option to traditional teaching to improve the quality of education in higher learning institutions by increasing students' participation, motivation, responsibility and autonomy (Gubaydullina et al., 2016; Ibyatova et al., 2018; Rahman, 2022). However, Dejene and Chen (2019) reported that, in modularisation, the students are at the heart of the teaching and learning process. The teacher is a facilitator and, instead of transferring knowledge, it is the students who have to be actively engaged in constructing knowledge, guided by the teacher (Dejene & Chen, 2019). This demonstrates the inclination of the Bologna modular toward student-centred model (Pupsiyanen et al., 2005). The modular approach also provides students with the opportunity to learn step by step by connecting theory to practice; to be assessed early, based on the learning outcomes, and to frequent feedback (Shchitov et al., 2015).

With the growing necessity to raise the quality of education, Rwanda did not evade the development of education at the international level brought by the Bologna system to harmonise higher education with that of other countries. The Bologna modular system was adopted to consolidate the learner-centred pedagogy at university level to increase the students' involvement in the class (Mbabazi Bamwesiga et al., 2013). This was done to encourage teachers to engage with students and cater to their individual needs, recognising their differences (Mugisha et al., 2010). Furthermore, it sought to integrate Information and Communication Technology (ICT) into biotechnology education to enhance the instructional process, fostering efficiency, interactivity, and interest among students (Iyamuremye et al., 2022). In the contemporary landscape, science education is viewed as a pivotal driver for economic growth grounded in knowledge, with biotechnology emerging as a particularly promising and innovative field in the 21st century (Kırbaşlar & Barış, 2016). Biotechnology's significance in everyday life is underscored by its capacity to address challenges across various sectors (Acarli, 2016; Qalbina & Ahda, 2019). Many nations have dedicated resources to revamping education systems to produce skilled professionals equipped with the requisite knowledge and values in biotechnology (Joshi et al., 2013; Lababpour, 2004; Nurse, 2016). In Rwanda, significant efforts and investments have been directed towards enhancing proficiency in science and technology education, particularly within higher education (MINEDUC, 2023), with the overarching aim of fostering a sustainable, knowledge-based economy. Biotechnology's adoption in Rwanda is envisaged to catalyse substantial economic development across diverse sectors. However, challenges persist, including limited ICT infrastructure, which underscores the need for strategic interventions to address such obstacles and realise the full potential of biotechnology education in Rwanda.

Biotechnology was introduced among programmes taught in higher education in Rwanda (MINISTERE, 2005). It prioritised and was expected to reduce unemployment through job creation among university graduates. Biotechnology was also adopted to maximise agriculture productivity and quality through overcoming challenges in the agriculture sector, and to achieve a modern market-oriented and climate-resilient agriculture (Dusi & Huisman, 2021). A National Biosafety Framework has also been developed to ensure and facilitate the development and intensification of safe applications of modern biotechnology for optimum benefits (MINISTERE, 2005). Rwanda also joined the Open Forum on Agricultural Biotechnology (OFAB) to enhance awareness and allow the population to share knowledge through the Forum on Agricultural Biotechnology.

Biotechnological approaches rely on improved breeding tools to create types suitable for sustainable agriculture. The primary research efforts are focused on improving tissue-culture procedures. Rwanda has yet to produce or commercialise genetically modified crops, indicating a significant gap in the country's biotech sector. To close this gap, there is an urgent need to develop a trained workforce, to cultivate competency, and to facilitate the dissemination of research findings and knowledge transfer. These activities are critical to laying the groundwork for long-term economic and social development in the biotechnology sector (MINECOFIN, 2015). Hence, higher education is required to connect to the demands and needs of the employment market. This requires schools to adapt for effective teaching and learning to produce graduates ready to compete in the labour market (Kırbaşlar & Barış, 2016). The effective teaching in this regard focuses on student learning, and this goes together with changes in teaching approaches (Friberg, 2015). As we stride forward into the expansive realm of scientific advancement, it becomes increasingly evident that biotechnology holds the key to our future prosperity. Within the halls of academia, it is imperative to arm our students with the requisite knowledge and skills to navigate this dynamic landscape adeptly. They are the vanguard of tomorrow, destined to confront the challenges and embrace the opportunities presented by biotechnology. Hence, the present study endeavours to unravel the intricacies obstructing the modularisation of biotechnology education at the University of Rwanda. By delving into the logistical and pedagogical hurdles, we aim to forge a path towards a more seamless integration of modularisation strategies into the curriculum. Through collaborative efforts and innovative solutions, we can empower the next generation to harness the transformative potential of biotechnology for the betterment of society.

Theoretical Framework

The present study, grounded in constructivism theory, aims to identify obstacles to and effective strategies for enhancing the teaching and learning of biotechnology. According to constructivism, knowledge is constructed based on prior knowledge rather than being discovered or inherited outright (Ogilvie & Baker, 1995). In line with this approach, students are encouraged to participate actively in knowledge construction through methods such as small group activities and problem-solving experiments (Rahman, 2022; Macnae et al., 1998). The use of instructional resources that engage multiple senses is also emphasised (Afurobi et al., 2015; Armstrong, 2011). Furthermore, constructivism advocates for the use of ICT tools to facilitate communication, thus enhancing interaction among learners (Iyamuremye, Nsabayezu, et al., 2022). Teachers in a constructivist learning environment are tasked with guiding students to deeper understanding and fostering autonomy in decision-making (Terhart, 2003). Furthermore, assessment methods should be authentic and provide timely feedback to support student progress (Amineh & Asl, 2015). The study focuses on exploring challenges and strategies for biotechnology education within the context of the University of Rwanda-College of Science and Technology, aligning with constructivist principles of hands-on learning, collaborative approaches, and knowledge construction. By investigating how these educational practices align with constructivism theory, the research seeks to promote a more effective and student-centred learning experience.

Contribution of the study to the existing body of knowledge

The significance of this study lies in its exploration of challenges and strategies for enhancing biotechnology education within a modularised context, addressing a notable gap in existing literature and catering to stakeholders including educators, curriculum designers, institutions offering biotechnology programmes, students, and industries reliant on a skilled biotechnology workforce. By offering context-specific insights and practical strategies for overcoming challenges, the research equips educators and curriculum designers with the tools needed to enhance curricula and improve education quality and relevance for students. Moreover, the study contributes to the broader discourse on pedagogical innovation in higher education, highlighting the potential of modularisation to elevate educational standards and meet the evolving needs of both students and industries, thus benefiting not only immediate stakeholders, but also the wider educational community embracing innovative teaching methodologies.

Problem statement

The agricultural industry is a key driver of economic growth in Rwanda, with the national goal of transitioning from subsistence agriculture to market-oriented methods by 2020 in order to meet the Millennium Development Goal of reducing extreme poverty (Diao et al., 2014). To achieve this vision, it is critical to build qualified human resource capital capable of undertaking effective agricultural research. While higher education is expected to play a crucial role in developing scientific and technological information to modernise the agricultural sector, the lack of skilled professionals in the field of biotechnology offers a considerable obstacle (Heinen, 2022). Despite the introduction of biotechnology education in Rwanda in 1993, there is a skilled labour deficit, hindering the use of biotechnology in agricultural research (Diao et al., 2014).

Limited research relying on external expertise hampers indigenous capability development, resulting in high costs and consistent unproductivity in the agriculture sector. Recognising biotechnology's potential for sustainable solutions, this study aims to enhance teaching and learning procedures at the University of Rwanda-College of Science and Technology. The goal is to close the competency gap, equipping graduates with the skills to provide domestic solutions and drive positive, long-term changes in the agricultural sector.

Research questions
The following research questions guided this study:

a) What challenges are faced by lecturers and students in teaching and learning biotechnology at UR-CST?
b) What possible solutions are required to enhance the effective teaching and learning biotechnology at UR-CST?

2. Literature review

In the domain of biotechnology education, both educators and students encounter formidable barriers that hinder effective teaching and learning. A plethora of studies have meticulously scrutinised these obstacles, spotlighting crucial challenges that demand attention. Foremost among these concerns is the accessibility and adequacy of instructional facilities, materials, and resources. Scholars consistently underscore infrastructure deficiencies, such as inadequately equipped facilities, which lead to overcrowded lecture halls, deficiencies in information and communication technology (ICT) resources, and constraints in laboratory and library resources (Jabbour, 2013). The literature elucidates several other salient issues. These encompass the lack of supportive school leadership, the dearth of stakeholder involvement in curriculum development and re-evaluation processes, insufficient backing for research and development, and the prevalence of traditional teaching methodologies (Jabbour, 2013; Severcan et al., 2000). Additionally, the failure to cultivate dialogue among stakeholders to champion educational reforms underscores the imperative for concerted efforts between institutions, authorities, employers, and the broader public to augment employability (Laze, 2021). The overreliance on a singular type of educational material in biotechnology instruction has emerged as another significant quandary (Kurniawati & Rahayu, 2014). In response to these challenges, the utilisation of Open Educational Resources (OER) has been posited as a potential panacea (Alves, 2011). However, impediments to accessing and organising these resources effectively impede their seamless integration into biotechnology teaching and learning (Alves, 2011; Glaze, 2018). In addition to these identified issues, delays in the procurement of educational materials further compound the challenges faced by educators and students (Bramble et al., 1985). Consequently, students may passively acquire knowledge from instructors when materials are not provided in a timely manner (Moyer et al., 2007). This critical review of the challenges inherent in biotechnology education, particularly within the Rwandan context, underscores the lacunae in current research and practice. By delineating these issues and their ramifications, this study endeavours to enrich the ongoing discourse pertaining to effective strategies for enhancing biotechnology instruction and learning. Besides the above obstacles, it was mentioned that the methods offered in classroom influence learning where students can be found in passive learning activities (Bosson et al., 2010; Ead & Inmetro, 2016). The lecture method is largely used at tertiary education level to deliver knowledge. The method of lecturing is accused of focussing less on learners, even if it has been shown that the method can be useful once the preparation of instructional materials take into consideration student's participation (Scherokman & Waechter, 2015). Integrating technology and new active methods of teaching can assist instructors to become more active facilitators of the learning process (Jagtap, 2016; O'Leary, 2023).

Kurniati and Ahda (2019) pointed out that a low level knowledge in biotechnology is associated with reading wrong and outdated sources of information, even if it is not easy to obtain a source of updated teaching materials (Halimah et al., 2019). Many theoretical principles, lack of interest and motivation were also found to be barriers to teaching and learning biotechnology (Huda et al., 2017; Shirani Bidabadi et al., 2016). The high number of students was also found to lead to a high ratio of student to teacher, reducing the attention paid to individual students (Ade, 2021; Kari Jabbour, 2013). In this context, large class size coupled with the shortage of time has also consequently produced frequent tests and quizzes without written and/or oral feedback (Darsih, 2018). The feedback develops motivation and interest of students and allows instructors to make adjustments to teaching and learning in response to assessment evidence. It was also revealed that when the students numbers are large, it becomes difficult to arrange class seating in a student-centred manner in a classroom, and even to serve them in terms of an electronic library, internet, electricity, electrical devices and satisfaction of their economic state (Khalid, 2022).

The study of Huda et al. (2017) added the lack of knowledge and experience, and that of teaching time as challenges to teaching biotechnology in higher learning institutions. The lack of knowledge and experience may influence the distribution of the curriculum among the teaching staff, depending on their knowledge and background, following the Bologna Process instruction (Ade, 2021). Once the modules are shared among the members, the efficiencies of the curriculum delivery increases (Sarah French, 1999). The design of the modules also matters and may provoke students to adopt a superficial or deep learning approach. The lack of the teacher's professional development was also shown as a challenge in teaching biotechnology, mainly when designing and implementing the modular system in the classroom (Sadiq & Zamir, 2014).

The factor of time was also reported. Insufficient teaching time and time to complete all assignments was mainly associated with an inadequate number of real teaching weeks in the academic calendar and the poor calculation of hours (Ade, 2021). In contrast to traditional learning, the Bologna Process stresses the importance of time regarding the studying time for students and that of teachers of designing activities, monitoring the ongoing of the learning process and facilitating learning activities (Sarah French, 1999). Thus, the short time allowed to cover the content and to meet all students' needs does not ensure students' employability.

As found by Bigler and Hanegan (2011): *Practical application increases the meaning of scientific knowledge when compared to conceptual reading. The majority of concepts in biotechnology are abstract, with foreign language that might be difficult to understand and communicate* (Zulpadly et al., 2022). Students prefer learning materials which allow the subject material that is not directly observable to be visualised and so to better understand the concepts. The use of pictures, figures, graphs and videos are the materials which may help the abstract process in biotechnology to be observed and understood (Jefriadi et al., 2018). The effective teaching and learning of biotechnology depends on how students interact with materials, and on their motivation.

The lack of experience and expertise, suitable activities, resources and time were also shown to be major difficulties in biotechnology teaching and learning (Dunlosky et al., 2013). The way students learn and where the learning takes place were shown to influence the abilities of students (Tye et al., 2013). Hence, there is a need to provide possible relevant resources to make the teaching and learning of biotechnology more meaningful.

In comparison to many other countries, biotechnology is a relatively new addition to Rwanda's educational scene. In Rwanda, many biotechnology studies focus mostly on agricultural biotechnology (Leonce et al., 2019; Lindiro et al., 2013; Mushimiyimana et al., 2011; Rukundo, 2015; Rukundo et al., 2013; Valery et al., 2014). However, there is gap in research in the area of biotechnology education. Detailed studies regarding biotechnology education at university level are lacking. Based on the information from reviewed literature, there is still noticeably little knowledge among university students and even a lack of competent personnel in the field of biotechnology. A study conducted in Rwanda about the biology concepts in the revised curriculum found that it was difficult to teach and learn the concepts linked to molecular biology and biotechnology (Byukusenge et al., 2022).

In this regard, the present study intended to investigate key issues that challenge the teaching and learning process of biotechnology of modules related to crop improvement at university level in the context of Bologna Process instruction. The study analysed various obstacles and suggested solutions for effective teaching. This could be important in determining the kind of relevant support needed to sustain the improvement in teaching and learning in biotechnology. Higher education is expected to show a key role in generating enough and appropriate competences. From this perspective, education provision at undergraduate level could fill the gaps in labour market demand and help to offer homegrown solutions to social and economic problems. In addition, it is hoped that the results will influence the Ministry of Education and other stakeholders to provide appropriate support.

3. Methodology

Research Paradigm and Design

The chosen mixed research approach in the current study, employing an explanatory research design, reflects a deliberate strategy to combine quantitative and qualitative methodologies. Grounded in pragmatism as the research philosophy and paradigm, this approach aims to maximise the depth of understanding derived from collected data, thereby facilitating comprehensive solutions to research questions (Creswell, 2014). This approach aims to offer a comprehensive understanding of the research subject by leveraging the strengths of both approaches. The sequential data collection procedure, beginning with quantitative data acquisition followed by qualitative exploration, was strategically designed to leverage insights gained from the initial phase, enhancing the overall analysis. This methodological choice aligns well with the study's objectives, enabling a holistic examination of the research subject and fostering a nuanced interpretation of findings through the integration of diverse data sources, ultimately enhancing the validity and robustness of the study's outcomes.

Study sampling

The present study consisted of 111 participants which included 109 students and two lecturers from the University of Rwanda-College of Science Technology. Only two lecturers were chosen because they are involved in the teaching and learning of biotechnology modules. The convenience sampling technique was used to select the participants, based on the idea they were available for the studies and the ones who had the information needed to answer the research questions (Helwig et al., 2012). The study was conducted at the College of Science and Technology as it is the main college of University of Rwanda teaching the pure sciences. The College is also taken as the source of competent human resources employed in various institutions dealing with the activities associated with biotechnology.

Data collection

The survey on challenges in teaching biotechnology employed a structured questionnaire to gather quantitative data from 111 participants, comprising both teachers and students. The questionnaire was meticulously designed, with Likert scales utilised across four sections to gauge various aspects related to teaching and learning (see Appendix). These sections encompassed factors limiting normal practices, access to information, availability and suitability of teaching materials, and adequacy of infrastructure. Participants rated statements on a scale ranging from "Strongly Agree" to "Strongly Disagree" or based on the availability and suitability of resources. To ensure a high response rate, hard copies of the questionnaire were distributed and collected directly, with incomplete submissions excluded from the analysis. The data analysis involved a combination of scores from the Likert scale responses. Responses indicating agreement ("Strongly Agree" and "Agree") were merged and classified as acceptance, and assigned a score of 3. Conversely, disagreement ("Strongly

Disagree" and "Disagree") responses were merged and scored as 1, indicating non-acceptance. Neutral responses were retained as such, earning a score of 2. This method facilitated the interpretation of the data, offering insights into the challenges faced in teaching and learning biotechnology. Overall, the research adopted a mixed approach with an explanatory research design, aiming to comprehensively understand the obstacles encountered in biotechnology education.

In this research endeavour, a comprehensive strategy was adopted to collect data, ensuring a robust exploration of the subject matter. The focal point of data collection was the implementation of a focus group interview (see Appendix), involving 12 students and two lecturers, strategically selected through purposive sampling. These participants were then divided into two groups of six students each, fostering diverse perspectives and enriching the depth of discussions. The interviews were conducted face-to-face during participants' free time, fostering an environment conducive to candid exchanges and genuine insights. Throughout these sessions, meticulous guidance was provided by the research protocol, allowing all participants to contribute actively to the conversation. Consent was obtained to record the interviews, supplemented by detailed notes to augment the captured data. Subsequently, all data were transcribed into a computer for thorough analysis, ensuring accuracy and accessibility of information.

Validity and reliability

Expert researchers thoroughly reviewed and validated the questionnaires, which were adapted for both teachers and students in biology instruction. The modified questionnaires were then delivered to a targeted group in a pilot research using the test-retest approach to determine instrument reliability. Iterative improvements were then made to improve the questionnaires' validity, demonstrating a dedication to building strong instruments for effective data collecting in the context of biology education (Creswell, 2014). The Cronbach-α coefficient was used to measure reliability and was found to be 0.84 which proves the consistency and stability of results from the instrument.

Method of data analysis

Quantitative data obtained were analysed by using descriptive statistics. Initially, the quantitative data were captured in the computer in an Excel sheet, coded and analysed by using frequencies, percentage and a table to present the findings. Qualitative data obtained after conducting interviews were transcribed, coded and classed into various themes. The information in the form of textual data from qualitative data, and observation were subjected to thematic analysis. The findings were interpreted, together with those from the quantitative part to gain more insight to the answers of the research questions.

4. Results

The present study sought information about what teachers and students view as key issues to the modular approach in the teaching and learning of biotechnology. The presentation of findings was covered in four parts. The findings included specific obstacles that are related to teaching and learning practices, the access to the information, materials used to support the teaching and learning process, and constructions where the activities related to teaching and learning take place. In addition, potential solutions to the identified challenges were suggested.

Barriers faced by teachers and students in teaching and learning biotechnology

a) **Barriers related to teaching and learning practices of biotechnology**

For this section, participants were asked whether or not they accepted the statements provided were issues encountered in the modular approach when teaching and learning biotechnology. All the teachers (100%) indicated the lack of training for their professional development. The lack of sufficient finance support for enough field trips (77.22%), maintenance assistance (74.31%), a laboratory technician (71.96%) and too much content in too little time (71.70%) were reported by a high proportion of participants, both teachers and students. These responses were followed by lack of information about learning styles (68.18%), the content of the module was naturally difficult (67.59%), feedback was late or not provided (66.98%), the high number of students in the classroom (66.97%), bureaucracy in administration procedures required to request laboratory or other materials (65.14%) and the lack of time for in-class activities other than teaching (64.81%). The use of classic teaching methods was selected by slightly less than two-thirds (63.30%) of the participants, while poor interaction between students and teacher was mentioned by less than half of participants (46.85%). The findings are summarised in Table 1

Table 1: Barriers related to teaching and learning practices of biotechnology

Barriers	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
Students have poor prerequisite knowledge	23.85	26.61	17.43	11.01	21.10
Teachers have little knowledge of the content	35.24	30.48	10.48	16.19	7.62
Students lack interest to the module	36.79	25.47	16.04	12.26	9.43
Poor teaching methods	8.26	11.01	17.43	32.11	31.19
Lack of teaching experience to adequately teach biotechnology	41.44	25.23	11.71	12.61	9.01
High number of students in classroom	11.93	11.01	10.09	32.11	34.86
Lack of time for in-class activities other than teaching	12.96	9.26	12.96	32.41	32.41
Feedback on continuous assessment is provided late	13.21	11.32	8.49	35.85	31.13
Poor interaction between students	17.12	25.23	22.52	25.23	9.91
Poor interaction between students and teacher	11.71	14.41	27.03	32.43	14.41
Lack of information on learning styles	10.00	11.82	10.00	36.36	31.82
Too much content in too little time	5.66	9.43	13.21	38.68	33.02
The content of the module is naturally difficult	11.11	9.26	12.04	37.04	30.56

Bureaucracy in administration procedures required for requests of lab and other materials	11.01	11.01	12.84	33.03	32.11
Lack of a laboratory technician	8.41	10.28	9.35	12.15	59.81
Difficult time table	18.02	14.41	42.34	15.32	9.91
Insufficient financial support for field trips	7.59	6.33	8.86	39.24	37.97
Lack of maintenance assistance	7.34	9.17	9.17	12.84	61.47
Lack of professional development training	0	0	0	0	100

Some of the results were supported by the responses from the focus group interview and classroom observation. Teachers stressed that *they were never provided with professional development training on how to implement the modular teaching approach in the classroom. It is better to think about regular professional development training even in order to integrate new teachers in new reforms.*

Both teachers and students reported that the *time allocated to the teaching is short compared to the content to be covered. Hence there is no time to conduct other sufficient activities supporting the teaching and even to support the students in need through tutorials within the allocated time.*

In addition, it was reported that *there is an intention of rushing to cover the content using teacher-based methods helping to deliver much content and to give the minimum required tests based on the credits of the module.*

Moreover a student reported that *the challenge is to study many things which are superficial; they only give the basic knowledge. It is important to give us all possible package which can help us to compete at labour market.*

Both teachers and students reported that *[the] large number of students leading to poor seating arrangement does [sic] facilitate the instruction process as it is not easy to supervise students' learning and to provide individual learning.* This was supported by an extract from student responses: *Yeah, he was arranging a field trip in RAB and in FDA, they refuse, telling him that we are many.*

The shortage of teaching time *does not allow providing regular and a variety of assessment activities and hence leading to the use of written assignments and quizzes. In addition, there is not sufficient time to mark and add appropriate feedback and give it on time to such number of students.*

Teachers stress that *it is not fair to teach biotechnology without lab practice. It is better to search for a lab attendant to assist during laboratory practical activities.*

Observation also revealed that the teaching process does not consider the use of active teaching methods; it was mainly based on the use of PowerPoint presentations. In addition, it was difficult to supervise student learning based on the seating arrangement which hindered the interaction between students and even between teachers and students. Moreover, the use of ICT tools was not easy, as in the case of non-functioning equipment, and it was difficult to access support in time.

b) Access to sources of information

For this section seeking information on access to information, the majority indicated that the internet (48.65%), the online services of the library (41.67%) and modules online (48.62) were available, while websites with relevant resources were rarely available (51.24%). The findings are summarised in Table 2

Table 2: Access to sources of information

Access to information	Not Available	Rarely Available	Sometimes Available	Available
Internet	5.41	13.51	32.43	48.65
Library online	19.44	16.67	22.22	41.67
Modules online	10.09	8.26	33.03	48.62
Websites with relevant resources	23.14	51.24	14.88	10.74

The interview conducted with students revealed issues related to access to sources of information: *We suffer from the limited access to network connection (internet). When we are inside the school, we go where there is a strong wireless to get access on online library or platform where the modules are uploaded. Once we return home, it is not easy for each student to get internet, considering our finance status.*

Another stresses this: *The college has to advocate for telecommunications companies to get affordable internet connection*.

c) Teaching and learning materials

With reference to learning material and books (50.45%) and handouts (52.25%) were reported to being suitable but insufficient, projectors (61.26%) and computers (30.63%) were unsuitable and insufficient. The greater majority of students and teachers indicated that they lacked laboratory products and equipment, and software (65.14%). The findings are summarised in Table 3.

Table 3: Teaching and Learning materials

Materials	None	Unsuitable and Insufficient	Suitable but Insufficient	Suitable and Sufficient
Books	4.50	9.01	50.45	36.04
Handout	6.31	33.33	52.25	8.11
Software	65.14	11.93	9.17	13.76
Computers	12.61	30.63	46.85	9.91
Projectors	12.61	61.26	14.41	11.71
Lab Products	78.70	9.26	6.48	5.56
Lab Equipment	73.39	14.68	4.59	7.34

During the focus group interview, students identified some challenges related to the support in their learning process in terms of materials:

Students mentioned that: *In general, learning material and resources are not enough to support our learning. Even for instructors, there are topics they do not find any materials* *to use. I can say that it is a challenge to teachers to apply[the] active learning approach. It is unbelievable to becomes competent products as intended by the modularization.*

Another added: *There is a problem about the hands-on activities; this is not an institution which is unable to provide materials for labs. There is a need of increasing the efforts in conducting practices as they do for theory part. If theory goes together with practices we can go outside there and compete and perform well.*

Teachers stressed this: *It is not fair to teach biotechnology without lab practice. The school may commit at least to avail the basic lab products and equipment. Regarding the conditions we working in, it is impossible to reach the planned learning outcomes.*

Another student reported that: *Most of us do not possess personal computers, and they are needed to help us to full the task given by our teachers. Some of the assignments are even given online and we are requested to submit the tasks at communicated date despite considering those challenges.*

Another added: *Our College does not provide us with all required resources. Therefore establishing partnership with other institutions will allow us to get access to relevant learning materials such as books, prepared courses, and recorded courses.*

Observation also revealed that there was a biotechnology lab without products and equipment. The textbooks for students and teachers were not sufficient. Often, the available projectors were not appropriate. Similarly, the computers in computer laboratories were too few for the number of students.

d) Infrastructure

The study also sought information on infrastructure. The majority of participants (73.87%) reported that lecture facilities were inadequate, while other facilities such as classrooms (68.81%), biotechnology (63.06%) and computer labs (49.07%), library (72.73%) were moderate. The findings are summarised in Table 4

Table 4: Infrastructure

Infrastructure	None	Inadequate	Moderate	Adequate
Classrooms	1.83	18.35	68.81	11.01
Biotechnology laboratory	8.11	18.02	63.06	10.81
Computer laboratory	8.33	31.48	49.07	11.11
Library	6.36	12.73	72.73	8.18
Lecture facilities	5.41	73.87	10.81	9.91

The response of one of the teachers was: *The classrooms are not adequate regarding the number of students in each classroom. It is not easy to reach everyone to give him or her special attention.*

In addition another added that: *Apart from inappropriate classrooms based on the number of students we teach, the lecturing rooms are inadequate and they are used by more than two lecturers, which hinder to serve students with low performance by alarming our colleagues.*

A student stressed this by saying: *Honestly I feel uncomfortable to enter and expose my weakness in presence of other lecturers.*

Teachers also pointed out the lack of ICT resources as a factor hindering the instruction process. They said that: *The classroom without fixed computers and projectors disturb the teaching process. It takes time to look for a projector and moving our computers.*

Based on observation, the school consists of buildings with classrooms that are no longer adequate for the number of admitted students. There was one moderate biotechnology lab. Staff rooms were too small to accommodate anyone other than lecturers. There was a physical library and ICT laboratories to serve both students and teachers with some seating.

Potential solutions to the identified challenges faced by teachers and students in teaching and learning biotechnology

To enhance the teaching and learning of biotechnology, implementing interactive and collaborative teaching methods, some important potential solutions include incorporating practical hands-on experience, and fostering continuous professional development for educators which can significantly contribute to a more effective and engaging biotechnology education. Additionally, promoting technology integration and creating supportive learning environments with adequate resources further reinforces students' understanding and application of biotechnological concepts. See Table 5.

Table 5: Strategies for improving the teaching and learning of biotechnology

Strategies	Explanations
Acting like a facilitator	The teacher only facilitates students to learn new things based on what they already know. This method makes the student responsible and engaged.
Teaching by using visual material	This makes the content more understandable as the students visualise what is being taught. Videos related to the teaching material can also be used to illustrate the processes which are very expensive in cases where the resources to be used are unavailable.
More practical experiments	Practicals clarify concept and abstract processes. In the laboratory, students also have the opportunity to interact and to learn by doing.
More application examples	Specific examples of applications of biotechnology connected to real-life situations can increase awareness about the benefit of biotechnology in everyday life.
More field trips	Field trips help to gain more knowledge about the application of the content of the module in a real-world situation. They also provide information about what is available in order to improve and where to focus contributions to address various issues.
Problem-based learning (PBL)	Early involvement of students in planning, development and implementation of projects assists in discerning where there is a problem to develop solutions.

Classroom discussion	Discussion that is guided and followed by presentation helps students to share knowledge and to help each other to build the new knowledge through answering an assigned task.
Feedback	It is not only important to show errors committed, but also to indicate where the students have to focus to improve in their learning, Specific feedback encourages students to perform well.
Internship	Internship helps students to become familiar with their future profession. It also helps them to gain more knowledge and experience to contribute efficiently in their future job.
Seminars	Seminars can increase students' interest and motivation toward the subject as they see and hear from the real role model.
Handouts	If handouts are accessible to all students, including possible updated content, various figures explaining various processes and reliable source of information for reference are helpful.
Recording lessons	School could avail facilities for recording lessons and students could use them in their free time to recall or check in case of challenges to better understanding.

5. Discussion

The findings of this study revealed a predominant use of teacher-based methods in conveying information, an approach which has been criticised for fostering passive learning rather than promoting deep knowledge acquisition (Nordqvist & Aronsson, 2019). Active participation was identified as essential for effective learning, with a modular approach offering a pathway to consolidate student-centred teaching methods, fostering competence in specific areas of study (Rahman, 2022). In this framework, teachers serve as guides, encouraging students to take responsibility for their learning and actively construct their knowledge (Rahman, 2022).

The integration of Information and Communication Technology (ICT) in instruction emerged as a facilitator of student-centred learning, transforming teachers into facilitators (Golshan & Tafazoli, 2014). Research suggests that ICT tools enhance student motivation and engagement, leading to improved learning outcomes (Freeman et al., 2014; Kari Jabbour, 2013; Scherokman & Waechter, 2015). However, challenges persist in maintaining and utilising ICT tools effectively, particularly in supporting laboratory experiments and practical activities (Alabadi, 2019; Acarli, 2016). While ICT tools offer avenues for exploring and interacting with new knowledge, they cannot fully replace hands-on laboratory experience (Millar, 2004). Despite this, ICT tools can supplement practical learning by illustrating complex concepts and facilitating virtual laboratory experiences (Alabadi, 2019). However, financial constraints often limit the effectiveness of field visits and practical experience (Acarli, 2016).

The inherently complex nature of biotechnology content underscores the importance of providing diverse learning opportunities, including hands-on activities and field visits, to deepen understanding (Natadiwijaya et al., 2018). However, time constraints necessitate a strategic balance between essential teaching and assessment activities within modular programmes (Akilli & Genç, 2017). Continuous assessment, tailored to module-learning outcomes, fosters deep learning and student autonomy (Dejene & Chen, 2019). Learning materials play a crucial role in supporting students' understanding outside of lectures. While hard copies of handouts and books remain primary resources, online libraries and modules offer additional support (Qalbina & Ahda, 2019). However, challenges exist in accessing online resources, particularly for students outside school premises (Sharma et al., 2018). Understanding students' learning styles is essential for adapting teaching strategies effectively (Aldajah et al., 2014). Modularisation necessitates a flexible approach to accommodate diverse learning styles, emphasising the role of teachers as facilitators and creators of conducive learning environments (Darsih, 2018). Timely feedback, including peer review, enhances student performance and engagement (Simpson & Clifton, 2016). However, the lack of feedback, particularly in large class settings, hampers student learning and interaction with teachers (Simpson & Clifton, 2016). Effective school leadership is critical for the success of modular programmes, providing support for student-centred approaches and teachers' professional development (Ross & Gray, 2006). The commitment of all stakeholders, including teachers, administrators, and policymakers, is essential for implementing effective educational reforms (Sarah French, 1999).

6. Conclusion and recommendation

This study reported the findings on the investigation conducted to determine the barriers limiting the process of teaching and learning of biotechnology, and of strategies to improve. The major barriers appear to be: the lack of laboratory facilities leading to no laboratory experiments being conducted, exacerbated by lack of laboratory technicians and appropriate administrative support to provide requested materials on time; huge and difficult content delivered by using classic methods without support of relevant ICT tools, associated with poor technical support to repair even the available tools; lack of information about learning styles; lack of time to conduct other in-class activities, to prepare handouts with enough information, to give feedback and the necessary attention to students when it is needed owing to the large class size. Poor planning of field trips and internship, and inadequate teachers' offices were also pointed out as constraints.

Acting like a facilitator, the use of visual materials, more examples of applications and experiments, classroom discussion, presentation, peer review feedback, field visits, introducing the approaches of problem-based learning (PBL), and reinforcing seminar and internship were among the suggested potential solutions. The findings of the present study will assist policy makers to intervene and overcome barriers in convenient ways. Knowledge of these findings may also facilitate or guide the revision of the curriculum accordingly.

The present study recommends an emphasis on the provision of adequate instructional facilities and materials for effective modular teaching and learning. School leaders need to maintain close relationships with stakeholders, such as teachers and students to ensure accurate and timely support. Additionally, investing in teacher training and adequate financing for higher education is crucial for successful implementation of modular teaching approaches, with further research needed to explore barriers and solutions on a larger scale.

Limitation of the present study
The present study was conducted in one college of the University of Rwanda with non-random samples of participants enrolled in the Department of Biology and attending the courses of biotechnology courses directed at crop improvement. The study could be conducted by including students and teachers from other colleges and private universities offering biotechnology courses related to crop improvement. This would enable a larger sample to be used to seek the necessary information and to check the consistency of our findings. In addition, the study focused on the factors limiting the teaching and learning of biotechnology and the strategies to improve, but did not test any of the suggested strategies.

7. Acknowledgements
The author addresses special thanks to the Department of Biology of University of Rwanda-College of Science and Technology for its assistance in meeting the participants.

Conflict of interest
The authors declare no conflicts of interest between them.

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Appendix

Questionnaire for students

Part I: Biographical questions: Answer each question by ticking in appropriate box:

- Gender: Male ☐ Female ☐
- Year/level of study: Level 1 ☐ Level 2 ☐ Level 3 ☐ Level 4 ☐
- Title of the module:

Animal and Plant tissue culture ☐ Recombinant DNA technology ☐

- Student Background/ Option of the student's degree at A level:

PCB ☐ MCB ☐ BCG ☐ Any other: …………

Part II: Which would be the barrier (s) influencing the current ways of teaching and learning? Please tick under the corresponding scale adjective. You may indicate more than one barrier and tick in corresponding box.

Factors	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
Students have poor prerequisite knowledge					
Teachers have little knowledge of the content					
Students lack interest to the module					
Poor teaching methods					
Lack of teaching experience to adequately teach biotechnology					
High number of students in classroom					
Lack of time for other in-class activities rather than teaching					
Feedback of continuous assessment is provided late					
Poor interaction between students					
Poor interaction between students and teacher					
Lack of information on learning styles					
Too much content in too little time					
The content of the module is naturally difficult					
Bureaucracy in administration procedures during request of lab and other materials					
Lack of a laboratory technician					
Difficult time table					
Insufficient finance support for field trip					
Lack of maintenance assistance					
Any other					

Part III: The Access to the source of information

Access to information	Not Available	Rarely Available	Sometimes Available	Available
Internet				
Library online				
Module online				
Websites with relevant resources				
Any other				

Part IV: Teaching and Learning materials

Materials	None	Non-suitable and insufficient	Suitable and insufficient	Suitable and sufficient
Books				
Handout				
Software				
Computers				
Projectors				
Lab Products				
Lab Equipment				
Any other				

Part V: Infrastructures

Infrastructure	None	Inadequate	Moderate	Adequate
Classrooms				
Biotechnology laboratory				
Computer laboratory				

Library				
Lecturers' offices				
Any other				

Part VI: What are the effective methods/strategies you suggest to improve the teaching and learning process of the biotechnology?

Methods/strategies	Why

<u>Questionnaire for teachers</u>

Part I: Biographical questions: Answer to each question by ticking in appropriate box

- Gender: Male ☐ Female ☐
- Qualification: Masters ☐ PhD ☐ Any other…………..
- Module taught:
- Animal and plant tissue culture ☐ Recombinant DNA technology ☐
- Year of teaching experience

Less than 5 years ☐ 5 -10 years ☐ More than 10 years ☐

- Year of teaching experience of the module

Less than 5 years ☐ 5 -10 years ☐ 10-15 years ☐ More than 10 years ☐

- Academic Rank

Assistant Lecturer ☐ Lecturer ☐ Senior Lecturer ☐
Associate Professor ☐ Professor ☐ Research professor ☐

Part II: Which would be the barrier(s) influencing the current ways of teaching and learning? Please tick under the corresponding scale adjective. You may indicate more than one barrier and tick in the corresponding box.

Factors	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
Students have poor prerequisite knowledge					
Teachers have little knowledge of the content					
Students lack interest to the module					
Poor teaching methods					
Lack of teaching experience to teach biotechnology adequately					
High number of students in classroom					
Lack of time for other in-class activities other than teaching					
Feedback of continuous assessment is provided late					
Poor interaction between students					
Poor interaction between students and teacher					
Lack of information on learning styles					
Too much content in too little time					
The content of the module is naturally difficult					
Bureaucracy in administration procedures during request of lab and other materials					
Lack of a laboratory technician					
Difficult time table					
Insufficient financial support for field trip					
Lack of maintenance assistance					
Lack of professional development training					
Any other					

Part III: The Access to sources of information

Access to information	Not Available	Rarely Available	Sometimes Available	Available
Internet				
Library online				
Module online				
Websites with relevant resources				
Any other				

Part IV: Teaching and Learning materials

Materials	None	Unsuitable and insufficient	Suitable and insufficient	Suitable and sufficient
Books				
Handout				
Software				
Computers				
Projectors				
Lab Products				
Lab Equipment				
Any other				

Part V: Infrastructure

Infrastructure	None	Inadequate	Moderate	Adequate
Classrooms				
Biotechnology laboratory				
Computer laboratory				
Library				
Lecturers' offices				
Any other				

Part VI: What effective methods/strategies do you suggest to improve the teaching and learning process of the biotechnology?

Methods/strategies	Why

Interview guide questions

1. What are the obstacles you meet related to the:
   1.1. Teaching and learning practices of biotechnology
   1.2. Access to the source of information related to biotechnology
   1.3. Teaching and learning materials used in the process of teaching and learning
   1.4. State of various constructions used in the teaching and learning process
2. What strategies do you suggest in order to improve the teaching and learning process?