International Journal of Learning, Teaching and Educational Research
Vol. 23, No. 1, pp. 469-501, January 2024
https://doi.org/10.26803/ijlter.23.1.23
Received Nov 18, 2023; Revised Jan 25, 2024; Accepted Feb 1, 2024

Teaching and Learning Biotechnology at University of Rwanda - College of Science and Technology: The Assessment of Teaching Practices and Learning Styles for Biotechnology Concepts Understanding

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Abstract. This study addresses the crucial need for assessing teaching practices and learning styles to improve students' understanding of biotechnological concepts and enhance overall learning outcomes. A mixed-method research design was adopted to collect and analyse data. The quantitative data were analysed descriptively, while qualitative data were analysed by thematic analysis. The sample consisted of two (2) teachers and 109 students. The techniques for sampling were convenience sampling for the survey and purposive sampling for the interview. Both teachers and students were involved in teaching and learning biotechnology courses related to the crop improvement. Questionnaires, interview, and classroom observation were used to collect data, which were quantitatively and qualitatively analysed. The study found that teaching methods such as semi-formal lectures, PowerPoint presentations, interactive lectures, blended methods, student presentations, and audio-visual techniques were commonly used. Formal authority, expert, and personal teaching styles were prevalent, with the facilitator style being the least utilized. Students primarily learn through auditory and reading styles, occasionally incorporating visual elements. Despite the emphasis on collaborative learning, student-based activities were not given significant consideration. The spectrum of these practices comprised a mix of student- and teacher-centred approaches with the dominance of the teacher-centred method. Thus, for effective teaching and learning, the present study suggests future research on the implementation of new innovative teaching strategies to help all students to develop autonomy and to learn according to their diversities regarding their learning styles.

Keywords: biotechnology; teaching and learning; learning activities; learner-centred

1. Background of the Study

Biotechnology is an interdisciplinary field which has significant potential for addressing global issues. To achieve this, effective and engaging education is crucial. Science and technology are taking the initiative in 21stcentury in education to improve social economic development (Smits, 2002). Biotechnology has emerged as a new science with potential to transform areas of industry, medicine, agriculture and to protect the environment (Das et al., 2023). International Service for Agri-biotech Acquisition Applications reported that the potential achievements in agriculture depend on biotechnology (Utomo et al., 2017). Wijerathna-Yapa and Hiti-Bandaralage (2023) demonstrated that tissue culture and recombinant DNA are technologies utilized to improve crops' agronomic traits, resistance to unfavourable environmental factors and enhanced nutritional values. However, risks and ethical problems associated with the practices of biotechnology in agriculture have led to the limitation of its usage (Montgomery, 2015). Thus, it is necessary to improve scientific literacy and knowledge in biotechnology. This will help educated people to make decisions in times of controversy, taking into account the potential benefits of biotechnology (Danies, 2023).

Biotechnology as a technology has been used for thousands of years in the process of baking bread, making wine and carrying out selective breeding to improve crop yield (McGloughlin, 1999). These processes are called traditional biotechnology. More recently, biotechnology developed practices related to the identification, isolation and manipulation of genes (Jauhar, 2006), which are considered as modern biotechnology. As a result, the application of modern biotechnology requires more advanced scientific knowledge. Education is then an important instrument for the development of a country to produce relevant knowledge and skills in biotechnology (Chabalengula et al., 2011; Qalbina & Ahda, 2019) while one of the targets of the 21st century is to generate quality human resources.

The government of Rwanda is promoting and supporting education in science and technology to build an economy that is based on knowledge (MINECOFIN, 2018). The emphasis is on tertiary education which is regarded as a primary tool for development and its mission is

"*To provide quality higher education programme that match the labour market and development needs of Rwanda for graduates who are capable of contributing to national economic and social needs and who can compete on the international labour market and that supports the development of the national culture, promotes lifelong learning, research, innovation and knowledge transfer* " (HEC, 2007).

In this way, the higher education system contributes to overcoming the problem of skills shortage in human resources associated with low productivity in various sectors, including agriculture. Comprehensive review and reform of the curricula in teaching and learning methods assure the link to the national goals, one of which is a knowledge-based economy, by including the requisite skills, competences, knowledge and attitudes for social and economic transformation (MINEDUC, 2008).

The reforms in teaching and learning methods mainly depend on the learning outcomes of the programme, student needs and the environment in which the learning process is taking place. The right choice of the methods helps students to master the content of the programme and know in which particular context the content is applied (Muhammad, 2019). The lecturing method is the common method used in high education system to deliver a large amount of content in a short time to a large number of students (Bligh & Francisco, 2007; Kari Jabbour, 2013; Abdulbaki et al., 2018; Muganga & Ssenkusu, 2019). It is often characterized by slide show of the content during which students receive the information and take notes while lecturers answer students' questions (Mohidin et al., 2009). Nowadays, the use of more students-centred methods is encouraged, regardless of classroom size (Olugbenga, 2021). Hence, teachers have to allow students to practise together or independently and then check their assessments to monitor their understanding. The modular system and the use of ICT were introduced in the tertiary education system to engage learners and to facilitate the instruction process, respectively (Mugisha et al., 2010).

The reform carried out in education is expected to improve the teaching and learning in terms of social and economic development. The teaching and learning of science and technology is regarded as a catalyst to accelerate the knowledge-based economy. Today much attention is paid to the teaching and learning of biotechnology (Severcan et al., 2000; Lababpour, 2003; Zhou et al., 2006). In Rwanda, biotechnology is offered both at university level and in advanced-level secondary schools. A Cartagena Protocol on Biosafety has been also already signed and a National Biosafety Framework (NBF) developed, not only to ensure and facilitate the development and intensification of safe applications of modern biotechnology for optimum benefits but also to guide institutional and human resources capacity building (MINISTERE, 2005). The overall invested efforts aim to produce relevant knowledge in biotechnology to benefit from the potential in the field by finding homegrown solutions.

However, the use of biotechnology lags behind owing to the limited capacity in local human resources (HEC, 2014; MINECOFIN, 2018). Past studies have pointed out the low level of knowledge in biotechnology in tertiary education (Sohan et al., 2002; Abuqamar et al., 2015; Alberro et al., 2023). This study investigates the distinctive teaching and learning methods employed in tertiary-level biotechnology education. The interdisciplinary nature of biotechnology, combining molecular biology techniques, genetic engineering, and practical applications, sets it apart from traditional science subjects. The research aims to uncover and understand the dynamic, application-oriented instructional approaches necessary for effective biotechnology education.

Theoretical Framework
Constructivism, as a learning theory, underscores the active role of learners in constructing their understanding of knowledge. Rooted in the idea that learning is an active and continuous process, constructivism posits that learners build new knowledge by reflecting on prior experiences and knowledge (Powell & Kalina, 2009). Jean Piaget's constructivism theory further emphasizes that learning involves active construction of knowledge through experiences and mental processes rather than passive absorption of information (Von, 2020). In the context of teaching biotechnology, constructivism aligns well with the dynamic nature of the field, encouraging students to engage actively, explore concepts, and construct their understanding (Bodner, 1986). The domain of learning emphasized in constructivism theory is one where learners are actively involved in shaping their knowledge through hands-on experiences and reflective processes.

In Rwanda's tertiary education, which follows a modular system, constructivism is recognized as a suitable approach (Dogra, 2010; Schendel et al., 2013) . The modular system, introduced during higher education reforms, aligns with the constructivist philosophy by placing students at the centre of the teaching and learning process (Hartle et al., 2012; Alam, 2016). Both the constructivist approach and the modular system emphasize active student engagement and autonomy. In a constructivist classroom, learners actively participate, fostering a democratic environment that is student-centred and interactive (Singh & Yaduvanshi, 2015). The teacher becomes a facilitator, guiding students toward autonomy and responsibility for their learning (Birse, 1996). This paradigm shift from a teacher-centred to a student-centred approach promotes independence and encourages learners to construct knowledge from personal experiences, emphasizing their active role in the learning process

Contribution of the Study to the Existing Body of Knowledge
This study was intended to improve biotechnology instruction at the University of Rwanda - College of Science and Technology by searching best practices and potential for supporting active learning. In the context of a growing and dynamic sector such as biotechnology, the findings of this study have the potential to increase educational quality and relevance considerably, linking the institution with industry expectations. Furthermore, it adds to the current literature by providing significant insights that might benefit educators, administrators, and policymakers in Rwanda and beyond. The study's identification of gaps and best practices can serve as a basis for future research and enable a more informed and holistic approach to educational development, resulting in more engaged and better-prepared biotechnology graduates. Furthermore, the research has the potential to impact the institution's reputation positively as well as the biotechnology sector, providing a substantial contribution to both academia and the broader community.

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 for the modernization of the agricultural sector, the lack of skilled professionals in the field of biotechnology presents 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. Recognizing 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 Objectives

a) To assess the teaching and learning methods used in teaching and learning biotechnology; and
b) To determine the learning style used by students in classroom for conceptual understanding of biotechnology.

Research Questions

a) What are teaching and learning methods used in teaching and learning biotechnology concepts?
b) What learning styles are prevalent among students for understanding concepts in biotechnology?

2. Literature Review

Biotechnology Teaching Methods

The literature sources have reported various approaches used to deliver knowledge and skills in biotechnology. For instance, Halimah et al. (2019) reported video modelling as an effective method for helping students to master biotechnology concepts. The research showed that the concepts of biotechnology seem to be abstract and the use of example-based learning showing a model in the video during explanation helped students to understand well (Dori et al., 2003). The concepts and processes of biotechnology that students cannot see directly were presented visually.

The study by Qalbina and Ahda (2019) affirmed that the integration of learning materials with audio-visual media enhances students' comprehension of biotechnology concepts, particularly when utilizing "micro-videos" in teaching (Li et al., 2016). Micro-videos, according to Liu et al. (2019), offer advantages such as making abstract concepts more tangible through continuous visual and auditory elements, and their effectiveness is heightened when combined with traditional teaching methods. İlkokul and Öğrencİlerİnİn (2013) demonstrated that incorporating materials such as animation, videos, and models enables students to perceive biotechnological concepts as real scenes, leading to more enduring learning compared to conventional lecturing. Furthermore, an experimental study by Altiparmak and Nakiboglu (2009) showed that hands-on paper model exercises, designed as a manipulative activity with inexpensive graphic materials, were more successful in teaching biotechnology than traditional instructional methods, by visualizing abstract material and stimulating students' motivation (Jefriadi et al., 2018).

The research showed that in higher education, most of institutions tried a blended method and found it to have a positive impact on students' learning and science process development skills compared to the conventional learning strategy in that students' character, learning ability and learning style were considered (Harahap et al., 2019). The flipped method, incorporating pre-class distribution of biotechnology content and diverse learning materials, enhances both student-teacher interaction and knowledge construction. This approach creates a more dynamic and engaged learning environment (Ferreira et al., 2018). Hence, class time is set aside for debates and teacher explanations where students encounter challenges when learning on their own.

The use of simulation and that of concept cartoons as teaching strategies of biotechnology also played a key role in developing the positive attitude of students towards the teaching of biotechnology and the future orientation of biotechnology-related fields (Montgomery, 2015). The virtual learning environment of biotechnology was also found to be a useful way of disseminating biotechnological knowledge to various groups of people (Ferreira et al., 2018). Other approaches such as discussions, field groups, role playing, reading articles, and conducting experiments were found to increase students' confidence (Dori et al., 2001). According to Othman and Amiruddin (2010a), for experiments, it is beneficial to utilize laboratory instructional tasks in teaching biotechnology subjects based on either research inquiry, problem solving, projects, argumentation or web-bases interdisciplinary approaches. The use of the inquiry approach to teach laboratory experiments to undergraduate students showed various advantages, including stimulation of students' interest toward the subject (Ketpichainarong et al., 2010). It becomes more meaningful when students are involved in designing and carrying out laboratory experiments and presenting the results (Geng & Alani, 2015).

On the other hand, a significant increase in students' knowledge and understanding about the methods of application of biotechnology was achieved through lectures, class discussions in small groups, journal reflection writing, service-learning projects and portfolios (Thomas et al., 2001). Colavito (2000) demonstrated that the use of case studies in biotechnology was successful in improving knowledge and understanding, higher order thinking skills at all academic levels and developing scientific and technological literacy. This was also supported by Şanlıtürk and Zeybek (2022) who showed that the cooperation between university with various stakeholders was valuable for biotechnology education in facilitating summer practical work, thereby helping students to become more familiar with the importance of biotechnology.

Teaching and Learning Styles and their Importance in Teaching and Learning Biotechnology

Besides the various approaches assisting in the teaching and learning of biotechnology, it is necessary to consider teaching and students learning styles to achieve higher learning outcomes as products of the process of teaching and learning. According to Wilson, (2000), teaching style is defined as the continuous and consistent behaviour of teachers in their interactions with students during the teaching-learning process. Teaching style is also the way in which teachers convey knowledge and information (Aldajah et al., 2014). Grasha (1996) identified five categories of teacher styles, namely expert, formal authority, personal model, facilitator, and delegator roles, encompassing a range of approaches, each with potential benefits and drawbacks. Balancing these styles is crucial for an effective teaching approach, as overemphasis on any one role may lead to intimidation, nervousness, feelings of inadequacy, or discomfort for students, emphasising the importance of a well-rounded and adaptable teaching strategy.

The choice of a teaching style depends on abilities, experience, beliefs about good teaching, preferences and the subject (Grasha, 1996; Beyhan, 2018). In this context, the knowledge that students gain in class depends on the extent to which teaching styles are compatible with their learning styles. According to Othman and Amiruddin (2010), learning styles are individual learning techniques that act with the environment to process, interpret and obtain information, experiences or desirable skills. Difference in learning styles among students explain the reason why the students do not receive, collate, process and interpret the information in the same ways (Menges & Davis, 1995). The learning style model of Fleming classifies students' learning preferences according to four modes, namely visual, aural, reading and kinesthetics, was used in this study (Luangrungruang & Kokaew, 2022). Visual learners thrive on visual stimuli, favouring information presented through pictures, charts, films, and graphics. Aural learners prefer listening and engaging in discussions, while reading-oriented students thrive on printed words and note-taking. Recognizing these diverse learning modes is crucial for educators to tailor their teaching methods, thereby creating a more inclusive and successful learning environment by accommodating students' preferences.

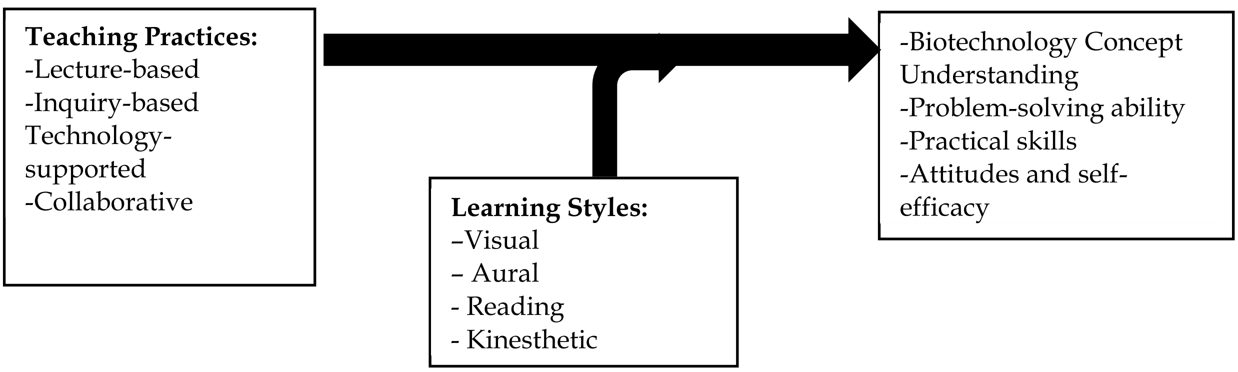
It is essential to know learners' characteristics in order to promote effective learning by developing appropriates strategies integrating different learning styles (Moussa, 2014). At the same time, diverse pedagogy strategies should be combined in every element of teaching to meet different learning styles (Othman & Amiruddin, 2010b) in order to maximize learning. When a teaching style does not meet the needs of a particular learning style, not much learning takes place. To help students to learn effectively, instructors need to adapt their teaching by taking into account the fact that learners are unique in terms of their styles of learning (Bhattacharyya & Shariff, 2014). Thus, learners have different ways of learning and remembering (Hussain, 2017). Being aware of this diversity among learners can help teachers to select appropriate learning materials and approaches to be used for effective and efficient teaching (Akram Awla, 2014).

Crop improvement is an important aspect of agricultural science that focuses on improving crop quality, production, and resilience in order to meet the expanding demands of a rapidly growing global population. Researchers hope to develop crop varieties with desirable traits such as increased resistance to pests and diseases, improved tolerance to environmental stressors such as drought or extreme temperatures, and increased nutritional content by employing a variety of scientific methods, including traditional propagating techniques, genetic engineering, and molecular biology (Pandey et al., 2019). This multidisciplinary method entails carefully selecting and manipulating plant genetic material to maximize desirable qualities while also reducing unwanted traits. Crop enhancement not only helps to provide food security, but it also plays an important role in sustainable agriculture by increasing resource efficiency and minimizing the environmental impact of farming operations. Continuous improvements in this subject have the potential to deal with increasing agricultural difficulties and adapt crops to changing climatic circumstances, resulting in a more resilient and productive global food supply (Gao, 2021).

The literature review emphasizes the importance of understanding individual learning styles in the context of teaching and learning processes, emphasizing their impact on student performance and the need for tailored instructional methods (Hamidah et al., 2009; Ginting, 2017). It emphasizes the necessity of teachers' being aware of their students' varied learning styles and developing evaluation procedures that account for these variances (Amir et al., 2011). The literature review reveals a substantial vacuum in biotechnology education as it does not investigate the practical use of pedagogical strategies or learning styles in this setting. The literature emphasizes the necessity of providing future scientists with appropriate knowledge, while also highlighting the scarcity of studies on biotechnology education at the university level in Rwanda. As a result, the study seeks to close this gap by examining current biotechnology teaching and learning practices and advocating for a more thorough understanding of instructional approaches in the subject.

Conceptual framework

Independent Variables **Dependent Variables**



Extraneous variable

Figure 1: Conceptual framework

3. Methodology

Research Paradigm and Design

The pragmatism research paradigm, when applied to investigating methods of teaching biotechnology, underscores a dynamic and flexible approach that prioritizes the practicality and effectiveness of instructional techniques. This research paradigm recognizes the importance of adapting teaching methods to the specific needs of students and the ever-evolving nature of microbiology science. Pragmatism encourages educators and researchers to employ an explanatory sequential design which involves the use of both quantitative and qualitative methods to gain a holistic understanding of how different pedagogical strategies impact student learning outcomes in biotechnology. By embracing pragmatism and explanatory sequential design in this study, researchers can optimize their exploration of innovative teaching methods in biotechnology, ensuring that the outcomes align with the real-world demands of both educators and learners.

The present study adopted an explanatory sequential design approach as a procedure for collecting, analysing and mixing quantitative and qualitative methods in a single or series of studies for a better understanding of the research problem (Creswell, 2014). In this context, data were collected in two phases to answer the research questions. Quantitative data were collected and analysed in the first phase (Creswell, 2014). The results obtained were used to determine the types of data collected in the second phase, namely the qualitative phase. This phase helped to obtain more specific and in-depth information to explain the findings of the quantitative phase. The use of multiple methods to collect data, known as triangulation, enables the comparison of data from multiple sources, thereby enhancing the trustworthiness of the study. It is important to ensure that the conclusions drawn from these different methods lead to the same outcome.

Study Sampling

The study's participants were lecturers and students from biotechnology courses focusing on crop development at the University of Rwanda's College of Science and Technology (UR-CST). The study used convenient sampling, with 109 students and two teachers chosen based on their availability and suitability to offer pertinent information. Purposive sampling, as recommended by Creswell (2014), was used to select 12 students for the interview component. The target population was UR-CST students that were chosen because of the College's unique role in providing education in pure sciences and technology in Rwanda, making it a valuable source of highly skilled teaching staff and students ready to contribute to biotechnology-related activities in future institutions and industries.

Data Collection

Data were collected by using three research instruments, namely a survey, interview, and classroom observation. Questionnaire was administrated to students during teaching time. To ensure a high return rate of responses, completed questionnaires were collected manually immediately after completing them. Despite being given instructions to follow when filling in the questionnaire, the participants were also given an opportunity to ask for clarification. The questionnaire employed a five-point Likert scale for sections seeking information on teaching and learning methods in biotechnology, teaching styles, students' learning styles, collaborative learning, and common teaching and learning activities. A three-point Likert scale was utilized for participants to provide information specifically related to certain teaching and learning activities such as invigilated continuous assessment tests, final examinations, and internships. Furthermore, during the qualitative phase, a specific focus group interview methodology was devised for students. Twelve (12) survey participants were intentionally selected and divided into two smaller groups of six each for the interview sessions. Purposive sampling was employed to select participants possessing the requisite information to address the research questions effectively.

The research employed a comprehensive approach to data collection, utilizing interviews, class observations, and survey questionnaires to ensure a robust qualitative dataset. Detailed notes taken during interviews not only supplemented open-ended responses but also added valuable context and insights to enrich the overall qualitative dataset. Special attention was given to participant interactions during interviews to maintain fairness and comprehensiveness in addressing study issues. Class observations, conducted eight times in four weeks, further contributed to the depth of the study by recording teachers' and students' activities, with transparency ensured by informing teachers beforehand. The use of various data collection methods, including surveys and focus group interviews, was aimed at enhancing the trustworthiness of the study, with corrections made based on interviewer feedback. Overall, the meticulous combination of qualitative techniques and observations facilitated a nuanced and credible exploration of the research objectives.

Validity and Reliability

The validity of the questionnaire, interview guide, and classroom observation were checked, and then reviewed by lecturers with expertise in biology education from the University of Rwanda - College of Education (UR-CE). This was done through face validity. This process eliminated irrelevant questions and words to ensure that the questionnaire included all aspects of the issues to be investigated. After making some changes, the questionnaire was subjected to the English language checkers to determine whether the statements used were straightforward and clear. Subsequently, further revision of the questionnaire was done to ensure the validity of the study (Creswell, 2014). The Cronbach-α coefficient was used to measure reliability and was found to be 0.84 which proved the consistency and stability of the instrument's results.

Method of Data Analysis

A mixed method was used to analyse the collected data. The quantitative data from the questionnaire survey and classroom observation data were recorded in the Excel spreadsheet in tabular format, and converted to percentages. In addition, the figures were also plotted to represent a clear picture of the findings of each section. All figures with corresponding percentages were organized in different categories in the results section. Therefore, the data obtained from the questionnaires and classroom observation were analysed using descriptive statistics with the help of Excel while the data on open-ended questions were analysed by using interpretive analysis. Qualitative data obtained from the interviews and classroom observation were analysed by using thematic analysis (Buetow, 2010). The interview data were fully transcribed from the audiotape. These data were recorded in the form of textual data. Data were first divided into segments which were in turn coded and categorized into different themes.

4. Results

In this research study, demographic information was gathered from a sample of 109 participants, consisting of 70 male students and 39 female students. Additionally, two male teachers were included in the study. The distribution of participants is summarized in Table 1, providing a clear overview of the demographic composition in the research sample.

Table 1: Demographic information

Participant	Gender	Number	Age
Students	Male	30	18-23
		20	17-22
		20	17-21
	Female	10	16-21
		15	17-23
		14	18-22
Subtotal		109	
Teachers	Male	1	41
	Male	1	54
Subtotal		2	

The results include the sections corresponding to teaching and learning methods, teaching styles, students' learning styles, collaborative learning, and common and particular teaching and learning activities. Both quantitative and qualitative data were reported for each section.

Teaching and Learning Methods

For this section, the participants, both teachers and students, were asked to rate teaching and learning methods of biotechnology. As shown in Figure 2, semi-formal lectures and lectures plus visual PowerPoint presentation methods were selected as frequently/always by the majority of participants at 81.44 % and 84.54%, respectively. Blended learning and students' presentations were selected as sometimes at 72.63% and 61.22%, respectively, while the use of audio-visuals and interactive lecturing was rated as sometimes at 59.14% and 56.99%, respectively. Finally, field trips were rated as rarely at 69.47% (See Figure 2).

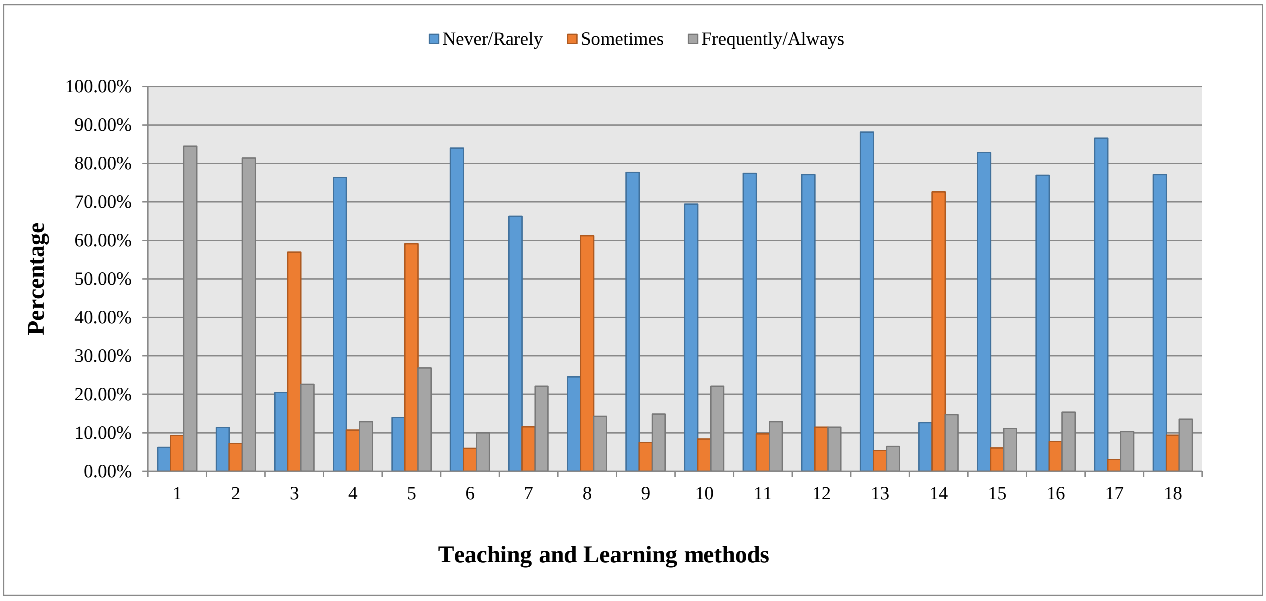


Figure 2: Teaching and learning methods of biotechnology

Notes: 1 = Semi-formal lecture, 2 = Lecture plus PowerPoint presentation, 3 = Interactive lecture, 4 = Lecture-discussion, 5 = Watching audio-visuals, 6 = Chalk and talk lecture, 7 = Research, 8 = Students' presentations, 9 = Classroom discussion, 10 = Field trip, 11 = Role play, 12 = Flipped, 13 = Debate, 14 = Blended method, 15 = Group projects, 16 = Case studies, 17 = Practical experiments, 18 = Seminar/workshop

Students also provided their points of view through a focus group interview on the teaching methods of biotechnology. Most of them reported the use of semi-formal lectures, lecture plus PowerPoint presentation methods. Interactive lectures and audio-visual methods were also mentioned in terms of teaching biotechnology. On the other hand, students reported field trips as the least used method. For instance, one student said that "*Our teacher delivers the content in different ways but most of times he comes in front of us and projects the PowerPoint slides containing the notes. He also gives us some examples which are not listed in the PowerPoint slides' content*" she added. Another student indicated that the module of R-DNA technology was delivered through an interactive presentation. She also added that during teaching and learning, they had an opportunity to asked questions and receive clarification. Furthermore, other students reported audio-visuals as a method also used in biotechnology class. One participant reported that "*Sometimes our teachers include audio-visual in the presentation to help us to understand more and for clarifying the concepts*. In this vein, one student explained that the use of audio-visuals has helped them to understand the process of conducting tissue culture in different environments.

However, most of the students reported field visits as the least used teaching method in biotechnology. For instance, one student said that " *Our teacher in this module of biotechnology gave us chance to visit the place conducting tissue culture experiment which helped me to understand more about the key concepts but when we went to field trip, we had shortage of time*". Another student added that "*Sometimes our teacher delivers hard content that requires going to the field to see how it is done in practice*". Moreover, students reported that they did not get enough time to practise what they had learnt in the classroom and field study.

The classroom observation also revealed that lectures plus PowerPoint presentations were used most frequently while students were listening, paying attention and taking some notes appeared throughout the class observations. The next most-used method noted was semi-lecturing where students were allowed to ask questions during the content presentation. Interactive lectures involving students in the teaching process and audio visuals materials such as short videos were also used to teach biotechnology.

Participants' Views on Teaching Styles in Biotechnology Classes
In this section participants were asked to rate whether teachers behave like experts, formal authorities, personal models, facilitators, or delegators. Most of the respondents considered teachers as experts, personal models, and formal authorities at the level of 87.50%, 83.51%, and 75.76%, respectively. The facilitator style was rated as sometimes by over half of the participants at about 58.14% and the delegator style as not noticed by only 13.98% (See Figure 3).

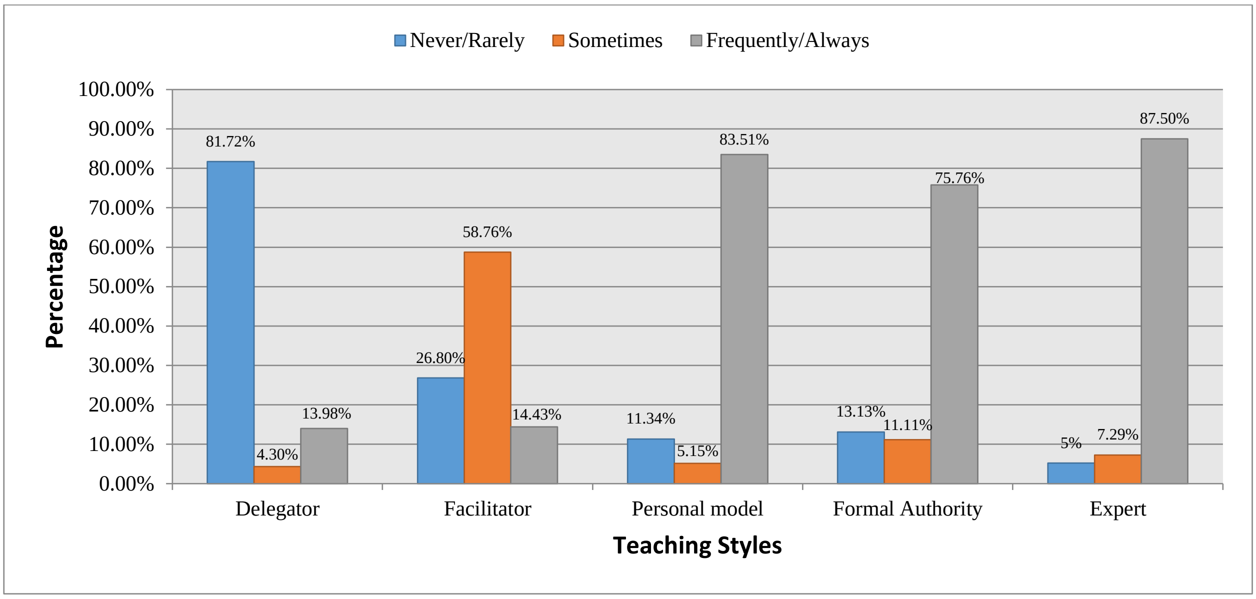


Figure 3: Teaching styles offered in biotechnology classroom

The findings of the interviews, in which students provided insights into their assessments of their lecturers' conduct and teaching styles, are directly related to the goal of assessing teaching and learning methods in biotechnology. The majority of students stated that the emphasis in their lessons was primarily on knowledge transfer from the lecturer to the students, with the lecturer seen as an expert and master of the subject. Students also reported minimal facilitation, with one particularly highlighting the lecturer's function as a facilitator. These findings offer insight on the typical teaching method in biotechnology courses, which emphasizes information transfer and positions lecturers as subject matter experts.

Students' Learning Styles based on Lecturers' Teaching Strategies
The present part collected information about students learning based on the strategies used by teachers in classroom. The responses from questionnaire indicated that aural and reading/writing learning styles were rated as the main

used styles in classroom and they were selected by good proportion of participants at 84.85% and 77.78%, respectively. In addition, the visual learning style is also used as indicated by69% students while kinesthetics was shown as the least style of learning at the level of 12.12%. (Figure 4).

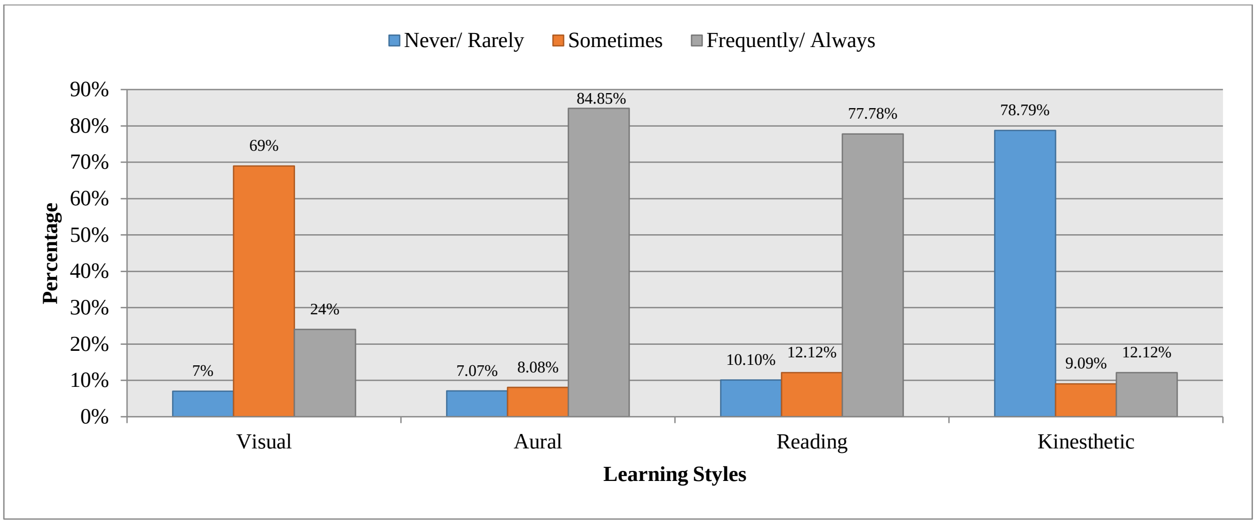


Figure 4: Students learning styles encountered in classroom based on lectures teaching strategies

From the focus group interview responses, the students also confirmed auditory and reading as the learning style most used by students in learning biotechnology, followed by the visual style. For instance, one student said that "*I get much by listening to what lecturer is presenting. I try to keep paying attention to him so that I cannot miss anything*". Another student stressed the reading and auditory styles and reported that *"I try to write some key points. When I reach at home during revising period, I remember what I have heard which facilitates me to understand very well when going through my pdf notes."* The use of visual style was also mentioned during an interview and one student said that "*While learning biotechnology, I used mainly to look and try to understand clearly through pictures, figures and videos shown by lecturer*". During classroom observation, listening style , exemplified by short videos, figures and pictures, and taking some notes was indicated.

Collaborative Learning in Biotechnology after Class

This section sought information on the weight students give to the collaborative learning after class to enhance their understanding and knowledge in biotechnology. They were asked to indicate whether it is important to collaborate with their peers to improve and increase their understanding and knowledge of biotechnology. The data shows that the majority of students (48.94%) attribute a high level of importance to collaborative learning, followed by an average level of importance selected by 23.40%, a low level of importance selected by 14.89% and a very high level of importance selected by 6.38%. No importance at all was also selected by 6.38 (Figure 5).

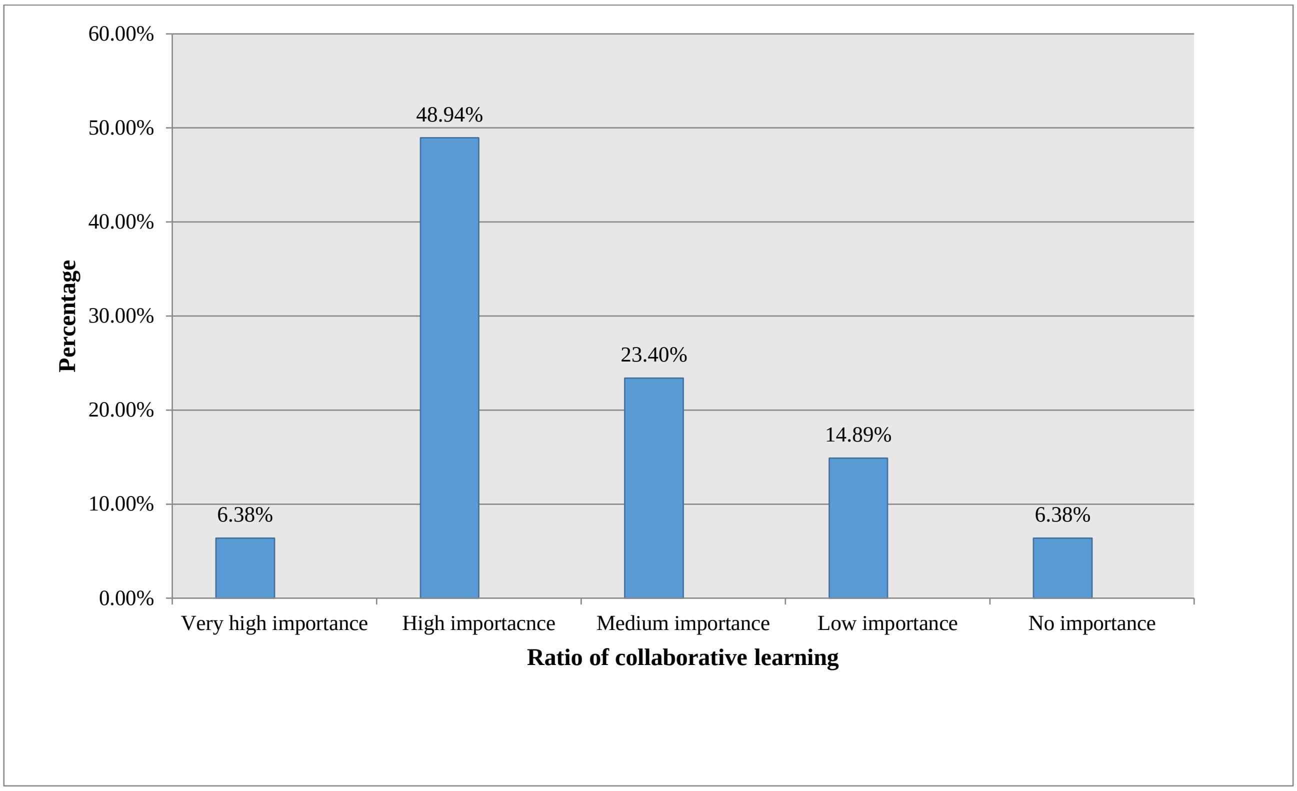


Figure 5: Ratio of the importance of collaborative learning

During the focus group interview the study also sought to determine why students indicated that it is important to collaborate with their peers. The main reasons provided by interviewees were that collaborative learning enhanced the exchange of ideas, critical thinking, and problem-solving, as well as encouraging discussion. One students reported that "*This module of biotechnology requires me to interact with others, it is a module that you cannot study it alone, while revising the content, I tried to interact with others sharing ideas on the different biotechnology concepts*". Another student stressed the importance of collaborative learning and reported that "*I like to join my classmates to discuss with them on encountered challenge*". The method of engaging with others involved collaborating in group work and completing assignments as a team.

Teaching and Learning Activities in the Biotechnology Classroom

This section reports on the information collected from participants on various teaching and learning activities used in the classroom to support knowledge construction in biotechnology. They were first asked to rate the frequency of following activities, namely individual work in class, written assignments, group work in class, oral presentations, laboratory reports, field trips, project work, and quizzes. The results revealed that quizzes, written assignments and field trip reports were selected by the majority, namely 81.76%, 81.04%, and 81.21% of respondents, respectively. In addition, individual work in class and oral presentations were rated as sometimes used by 66.10% and 65%, respectively. Moreover, laboratory reports, group work in class and project work were rarely used as reported by 85.00%, 82.46% and 80.00% of the students, respectively (Figure 6).

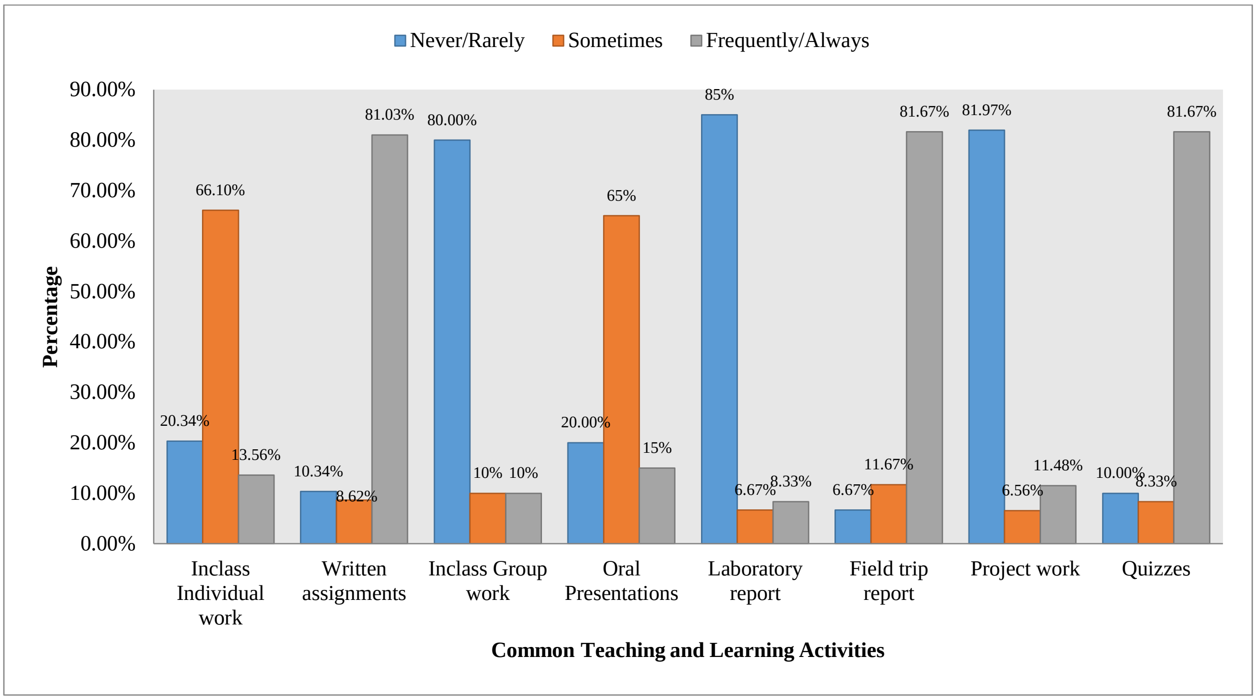


Figure 6: Common activities used to support the process of teaching and learning of biotechnology

The study also sought information on particular activities which are prepared and arranged at specified periods outside the teaching time to assess or to reinforce the knowledge gained during class time. Participants were asked to rate three of these activities, namely invigilated continuous assessment tests, final examinations, and internships. The results revealed that invigilated continuous assessment tests, final examinations and internships were almost similarly rated by the majority of respondents at 73.33%, 88.14 % and 82.76%, respectively (Figure 7).

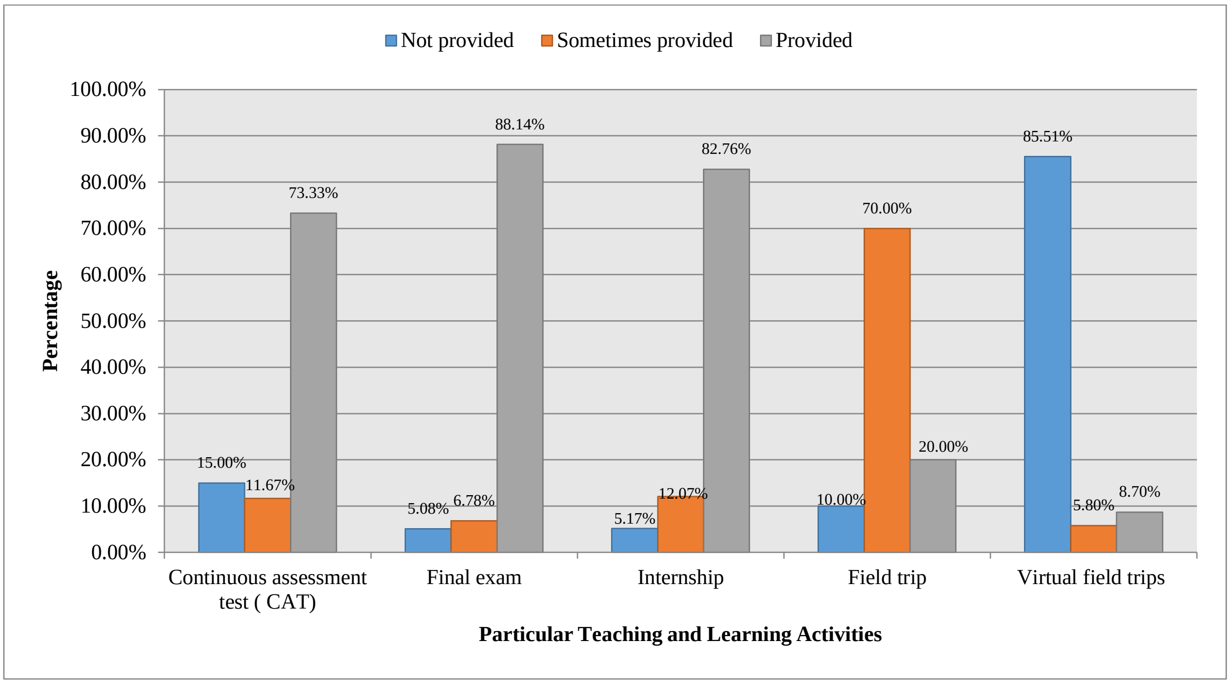


Figure 7: Particular teaching and learning activities

During discussions, students also indicated the types of activities that supported the process of teaching and learning biotechnology. Quizzes and assignments frequently were mentioned as the most predominant activities used by their lecturers apart from common admission tests (CATs) that are administered for a specific period. One student said that "*Regular quizzes help us to be attentive but CATs help us more because when we are preparing CATs we go deep the concepts and do individual research*". The students also reported that they had challenges when doing practical tests. For example, one student said that that "*…we have only a problem of practical. R-DNA technology is a module which requires many practices. For example, we know all the process of making R-DNA molecules in theory but we don't know actually how it is done in practice, a practical session is needed for putting theory into practices*"

During classroom observation, the students were given few individual activities and regular quizzes. Unscheduled quizzes were dominant as compared to short individual work and individual questions to respond to orally. Whenever necessary, teachers also assigned written homework relating to classroom activities to support the teaching and learning processes.

5. Discussion

The major findings of the study underscore the effectiveness of diverse pedagogical approaches in teaching biotechnology within the framework of the constructivist theory. Traditional methods such as semi-formal lectures and lectures supplemented by visual aids such as PowerPoint were identified as effective means of conveying complex concepts. The blended method, which combines various teaching techniques, aligns with the theoretical underpinning of constructivism by accommodating different learning styles and preferences. Notably, the study emphasizes the empowerment of learners through student presentations, fostering a dynamic learning environment and aligning with the constructivist principle of active student involvement. Additionally, the incorporation of field trips and the use of audio-visual materials were highlighted as essential components providing a real-world context, reinforcing the relevance of experiential learning within the constructivist framework.

However, the dominance of teacher-centred methods, as revealed in the findings, suggests a potential misalignment with the constructivist theory, which encourages a more learner-centred approach. The study advocates for a nuanced consideration of specific combinations of teaching strategies tailored to the nature of the topic being taught, emphasizing the importance of flexibility and adaptability in teaching biotechnology. Classroom observations and interviews further support the efficacy of strategies such as the use of audio-visuals, particularly through video modelling examples, in enhancing students' understanding and concretizing abstract concepts in biotechnology (Subagja & Pakuan, 2023). This alignment with constructivist principles reinforces the value of adopting innovative and student-engaging strategies in teaching biotechnology for effective learning outcomes.

In this study, a blended strategy was sometimes used as a way to assess students independently. The blended strategy based on independent learning was reported in the research conducted by Harahap et al. (2019) and was found to enhance students' science process skills. Teaching methods were found to influence students' learning (Dunlosky et al., 2013). It was mentioned that, at the university level, methods which engage students such as those focusing on students' interaction, classroom discussions, demonstrations and practicals, lectures with the use of PowerPoint and free-flow discussions are the preferred (Shirani Bidabadi et al., 2016).Therefore it is up to the teacher to select suitable strategies which allow all learners to participate actively.

In the classroom, instructors behave in different ways, commonly called teaching styles (Grasha, 1996). The results of this investigation indicated that teachers regularly behave like experts, formal authorities, personal models or sometime like facilitators. Experts and formal authorities display a teacher-centred approach. Teaching at university was also recommended to emphasise student-centred strategies (Barrett et al., 2018). The participants also described their lecturers as facilitators and delegator models. For this reason, it is also worth focusing more on the facilitator style and integrating the delegator teaching style in the classroom. In this case, the teacher is expected to facilitate the learning process and help students to be autonomous and responsible for their own learning (Wilson, 2000). Teachers need to recognize that learners have diverse ways of learning which influence how they receive, process, and interpret knowledge. Consequently, it is essential to acknowledge and address the variety of learning styles among students during the teaching process. However, an analysis of gathered data indicates a predominant focus on students with auditory and reading preferences, neglecting those with a visual learning style. Unfortunately, students with a kinaesthetic learning style are largely overlooked in the instructional approach.

The research revealed that 87.50% of respondents view teachers as experts in their fields, aligning with the traditional teacher-centred model. Additionally, 83.51% saw teachers as personal models, shaping students' values, behaviour, and character. However, only 58.14% rated teachers as facilitators, suggesting room for more student-centred and collaborative approaches. To enhance education quality, teachers should strike a balance between being experts and facilitators, creating an environment where students actively engage with knowledge and explore their learning pathways. This research can guide efforts to improve teaching methods and classroom dynamics.

In the case of this study, learning through experience and hands-on activities which are characteristics of the kinaesthetic style were not considered although it was revealed as a dominant model among students' learning sciences (Subagja & Pakuan, 2023). Hence, the teacher has the responsibility to apply suitable strategies based on learning styles to encourage and engage all students (Hussain, 2017). If not, this may lead to the lack of motivation of students owing to inappropriate learning styles which have a negative impact on their performance (Osuala et al., 2018). It was reported that it is difficult for students to learn when the way of teaching is not adapted and does not meet the needs of their learning styles. This explains why learning and remembering among students occur in different ways (Bhattacharyya & Shariff, 2014).

The study's findings also revealed that, following the class sessions, a considerable majority of the students acknowledged the importance of collaborative learning in boosting their grasp of biotechnology. Collaborative learning is especially useful when dealing with difficult subjects when the professors' explanations alone may not be adequate for a comprehensive understanding. The students' collaboration is significant to their performance and demonstrates their interest in the subject; while their interest in the subject helps them to learn effectively (Megahati et al., 2018). It is necessary to encourage students to be collaborative; this will help the country to achieve its higher education goal of producing graduates with team-work skills.

The study revealed additional activities beyond time-bound assessments, including quizzes, written assignments, field trip reports, and working individually in class, as integral components supporting the teaching and learning process. However, activities fostering student engagement through discussion, such as in-class group work, laboratory reports, and project work, were found to be relatively limited. These student-centred activities demand significant time for teachers to guide and facilitate the learning process, particularly in tasks involving experiment design, data collection, analysis, real-life application, and presentation of findings, as exemplified in laboratory sessions.

The findings underscore the importance of encouraging and supporting teachers to incorporate more student-centred activities into the curriculum, acknowledging the time investment required for effective implementation. The study conducted by Orhan (2018) revealed that involving students in laboratory sessions improved content knowledge, increased enjoyment and interest as well as developing and supporting 21st century skills (Megahati et al., 2018). In addition, the author mentioned that team-based activities such as projects increase awareness of biotechnology and promote active learning. Besides providing more insight regarding the content, field trips were also shown to develop data collection, reporting and presentation abilities (Jing, 2013). Biotechnology is an application science; therefore, various activities are needed to enhance theoretical knowledge. Özel (2022) highlighted that combining theory and practical activities supports learning. In addition, activities indicate areas for improvement, thereby enabling teaching and learning strategies to be adjusted (EldaKılıç et al., 2012).

The objectives were reached by performing a detailed assessment of the teaching and learning methods used in biotechnology education, which included an analysis of several instructional approaches. Surveys, interviews, and classroom observations were also used to determine students' learning methods regarding conceptual knowledge of biotechnology, resulting in a thorough overview of the educational landscape in the subject. The triangulation of data from multiple sources permitted a comprehensive examination of the effectiveness and alignment of teaching approaches with students' learning styles in the context of biotechnology education.

6. Conclusions and Recommendations

The current study intended to investigate biotechnology teaching and learning strategies. Data analysis demonstrated that a mix of educational methods, such as lectures with visual PowerPoint, semi-formal lectures, blended approaches, student presentations, audio-visual content, interactive lectures, and field trips were beneficial. During instruction, teachers primarily adopted the roles of experts, formal authorities, and personal models. However, the study found a bias towards visual and aural while ignoring kinesthetic learners. Participants noted that present teaching methods, while time-consuming, did not adequately engage kinesthetic learners. The university-level study is an invaluable resource for educational policymakers and stakeholders, offering insights into the quality of biotechnology teaching and learning. While providing light on current procedures, more research is suggested into the fundamental motivations behind these methods.

While the study recommends a shift towards a student-centred approach with an emphasis on active learning and creative methods, it is essential to acknowledge certain limitations. First, the feasibility and practicality of implementing these recommendations may be constrained by institutional resources and existing structures, posing challenges to the widespread adoption of student-centred techniques. Additionally, the variability in subject matter suggests that a flexible approach involving a mix of student-centred and teacher-centred techniques may be necessary; however, this might be hindered by curriculum constraints or standardized testing requirements. The promotion of lifelong learning and tailored strategies for individual student needs may face limitations in terms of scalability and institutional support.

Moreover, the incorporation of student-centred activities such as group projects, internships, and field trips may encounter logistical challenges, particularly in resource-limited settings. Collaborative activity design, while beneficial, may require additional time and training for effective implementation, raising concerns about the workload on educators. Lastly, the recommendation for continued training in new teaching methodologies highlights the importance of professional development; nevertheless, potential limitations in terms of time, funding, and institutional prioritization may affect the feasibility of such ongoing training for academic staff. There is a need for collaboration and communication between policy makers, curriculum designers, and module writers to ensure that educational policies, curricula, and learning materials are designed to support the transition to student-centred approaches and the integration of diverse, interactive teaching methods.

Limitation of the Present Study

This study was restricted to a single college at the University of Rwanda, focusing specifically on the subject of crop improvement within biotechnology. Future research opportunities lie in extending the scope to encompass other biotechnology subjects and involving private universities with undergraduate programs in biotechnology, thereby providing a broader perspective on teaching and learning practices in this field to aid educators in adapting effective methodologies.

Acknowledgements

The authors address special thanks to the Department of Biology of the University of Rwanda - College of Science and Technology for its assistance in meeting participants.

Conflict of interest

Authors declare no conflicts of interest.

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Appendix

Questionnaire for students

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

- **Gender**: Male ☐ Female ☐
- **Year/level of the 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: This part investigates the ways that are used to teach the module and how often these ways are used. Please tick where it is appropriate. You may tick more than one way and tick in appropriate box:

Methodology	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Semi-formal lecture					
Lecture plus visual PowerPoint					
Interactive lecture					
Lecture-discussion					
Watching audio-visuals					
Chalk and talk lecture					
Guest speakers					
Virtual field trip					
Structured exercises					
Set readings/Research					
Students' presentation					
Classroom discussion					
Questioning					
Self-study					
Field trip					
Role play					
Flipped					

Jigsaw					
Debate					
Peer-teaching					
Blended method					
Group projects					
Case studies					
Practical experiments					
Seminar/Workshop					
Any other (Please specify)					

Part III: Please indicate the teaching styles that you use and how often they are used when delivering the course:

Teaching style	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Expert (Teacher has knowledge about the subject and plays a role of knowledge source for the students).					
Formal authority (Teacher is authoritarian in the knowledge about the subject and students should follow the standards set by the teacher).					
Personal model (Teacher serves as a model for students in what he/she says, does and demonstrates/ teacher's behaviour influences students' development).					
Facilitator (Teacher guides students to learn new things based on what they already know and facilitates the learning process)					
Delegator (Teacher gives tasks to students and encourages them to work independently or in a self–directed manner).					

Part IV: Please indicate the learning styles that you use and how often they are used depending on how the course is delivered:

Way of learning	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Visual					
Aural					
Reading					
Kinesthetics					

Part V: Please indicate how often the ways provided are needed to be used to enhance knowledge gained in classroom:

Way of learning	No importance (1)	Low importance (2)	Medium importance (3)	High importance (4)	Very high importance (5)
Collaborative learning					

Part VI: Please indicate to what extent the following activities contribute to the achievement of the module outcomes:

Activities	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Individual work in class					
Written assignments					
Group work in class					
Oral presentations					
Laboratory report					
Field trip report					
Project work					
Quizzes					
Any other (Please specify)					

Part VII: Please indicate whether the following activities are provided to support teaching and learning:

Activities	Not provided (1)	Sometimes provided (2)	Provided (3)
Continuous assessment tests (CAT)			
Final exam			
Internship			
Field trip			
Virtual field trips			

<u>**Questionnaire for teachers**</u>

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

- **Gender**: Male ☐ Female ☐
- **Module taught:** Animal and Plant tissue culture ☐ Recombinant DNA ☐ technology
- **Academic Rank**
  Assistant Lecturer ☐ Lecturer ☐ Senior Lecturer ☐
  Associate Professor ☐ Professor ☐ Research professor ☐

Part II: This part investigates the ways that are used to teach the module and how often these ways are used. Please tick where it is appropriate. You may tick more than one way and tick in appropriate box.

Methodology	Never (1)	Rarely (2)	Sometime (3)	Frequentl y (4)	Always (5)
Semi-formal lecture					
Lecture plus visual PowerPoint					
Interactive lecture					
Lecture-discussion					
Watching audio-visuals					
Chalk and talk lecture					
Guest speakers					
Virtual field trip					
Structured exercises					
Set readings/Research					
Students presentation					
Classroom discussion					

Questioning					
Self-study					
Field trip					
Role play					
Flipped					
Jigsaw					
Debate					
Peer-teaching					
Blended method					
Group projects					
Case studies					
Practical experiments					
Seminar/workshop					
Any other (Please specify)					

Part III: Please indicate the teaching styles that you use and how often they are used when delivering the course:

Teaching style	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Expert (Teacher has knowledge about the subject and plays a role of knowledge source for the students).					
Formal authority (Teacher is authoritarian in the knowledge about the subject and students should follow the standards set by the teacher).					
Personal model (Teacher serves as a model for students in what he/she says, does and demonstrates/ teacher's behaviour influence students' development).					

Facilitator (Teacher guides students to learn new things based on what they already know and facilitates the learning process)					
Delegator (Teacher gives tasks to students and encourages them to work independently or in a self–directed manner).					

Part IV: Please indicate the learning styles that you use and how often they are used depending on how the course is delivered:

Way of learning	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Visual					
Aural					
Reading					
Kinesthetics					

Part V: Please indicate to what extent the following activities contribute to the achievement of the module outcomes:

Activities	Never (1)	Rarely (2)	Sometime (3)	Frequently (4)	Always (5)
Individual work in class					
Written assignments					
Group work in class					
Oral presentations					
Laboratory report					
Field trip report					
Project work					
Quizzes					
Any other (Please specify)					

Part VI: Please indicate whether the following activities are provided to support teaching and learning:

Activities	Not provided (1)	Sometimes provided (2)	Provided (3)
Continuous assessment tests (CAT)			
Final exam			
Internship			
Field trip			
Virtual field trips			

Interview guide questions:

1. What are the methods that are mainly used by lecturers when teaching biotechnology?
2. What do you think about the methods that are used?
3. What do you think about the role you can attribute to your lecturers based on how they behave when teaching?
4. How do the ways used by your lecturers when teaching help you in your differences in terms of learning styles? Does each of you find her/himself helped?
5. What do they give you as assessments to evaluate the achievement of the learning outcomes?
6. Are other kind of activities provided to help you to understand biotechnological concepts?